Service Manual

Sabre 180

ELECTROSURGICAL UNIT

ConMed® Corporation

LIMITED WARRANTY

For a period of two years following the date of delivery, CONMED Corporation warrants the Sabre 180 Electrosurgical Unit against any defects in material or workmanship and will repair or replace (at CONMED's option) the same without charge, provided that routine maintenance as specified in this manual has been performed using replacement parts approved by CONMED. This warranty is void if the product is used in a manner or for purposes other than intended.

U.S. Patent Nos. 4,569,345 - 4,617,927 - 4,848,335 - 4,961,739 and other patents pending.

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Mailing Address:
310 Broad Street
Utica, New York 13501

Shipping Address:
7211 S. Eagle St.
Englewood, Colorado 80112

For Technical Services or Return Authorization Phone:
303-699-7600 / 1-800-552-0138

For Customer Services or to order parts phone:
1-800-448-6506 or contact your
CONMED Representative.

The revision level of this manual is specified by the highest revision letter found on either the inside front cover or enclosed errata pages (if any).

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Unit Serial Number _____

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General Information

Section 1.0

The Conmed Sabre 180 Electrosurgical Unit (ESU) provides the modern surgicenter and office clinic with a broad range of electrosurgical capabilities. It is suitable for use in minor, general and laparoscopic procedures. The bipolar option extends applications to gynecological, neurological and other microsurgery. CONMED offers other higher powered ESUs better suited to the most demanding procedures, such as transurethral resections.

Salient features of this ESU include:

•DIGITAL KNOB POWER CONTROLS: Combines the speed and ergonomics of analog controls with the precision of pushbuttons.

•LAST USED SETTINGS ON POWER UP: Power and mode settings used during previous procedures are automatically restored when unit is turned on, minimizing preop setup effort. Optionally, the unit may be configured to default to zero power and standard modes. In either case, the previously used A.R.M. single/dual pad mode selection appears every power up.

•ASPEN RETURN MONITOR: When used with A.R.M. or compatible dual-foil return electrodes, the Aspen Return Monitor (A.R.M.) provides an extra margin of safety against possible patient burns at the return site. The Resistance Indicator displays the resistance of the patient measured between the conductive contacts of the return electrode. This information can be used to note high risk patients and to indicate a loss of electrode contact with the patient. The A.R.M. also allows use with non-monitoring electrodes when set to the Single Foil mode.

•ISOLATED OUTPUT CIRCUITRY: This feature minimizes the probability of alternate ground site burns. Complies with all current international standards for RF leakage.

•INDEPENDENT OUTPUTS: Only one output is active at a time for maximum patient and operator safety. Interlocked controls prevent mishaps in the event of conflicting commands.

•POWER ADJUSTABLE WHILE ACTIVATED: The power settings can be adjusted while the unit is activated. The change is limited to the greater of $\pm$ 5W or $\pm$ 25% of the power setting at the beginning of the activation.

•VERSATILE, EFFECTIVE, MONOPOLAR CUTTING: A selection of three different crest factors provide the user with a range of hemostasis, from negligible for minimal-damage biopsies, through a moderate blanch for ordinary incisions to near-coag quality heavy hemostasis. A broad load regulation helps sustain an effective cutting arc in both wet and dry fields.

•CIRCUIT REDUNDANCY: This feature, in conjunction with a fault tolerant design, provides a wide safety margin against catastrophic failures.

•MICROPROCESSOR CONTROL: Provides the user with a superior degree of safety and control in solid state electrosurgery. The programmed intelligence of the microprocessor has been exploited to provide accurate, well controlled therapeutic power, digital power display, and a comprehensive set of internal diagnostics which continually guard against the consequences of an internal failure. Internal fault isolation simplifies troubleshooting to ensure a minimum delay in returning the unit to service.

•FULGURATION/COAGULATION: Up to 80 watts of high crest factor coagulation with over 5000V peak to peak output voltage provides effective contact dessication as well as easy fulguration of diffuse bleeders.

•IMPROVED BIPOLAR: Optionally available as a footswitched alternate coagulation mode, the Sabre 180 bipolar is designed to start quickly and conclude gracefully with minimal sparking and tissue sticking.

•SIMPLIFIED CONTROLS: The user may command the full range of capabilities of the Sabre 180 by means of a few easily understood controls.

•RUGGED, HIGH-EFFICIENCY CIRCUITRY: Cool, long-life operation. There are no fans to compromise the sterile field.

•CIRCUIT PROTECTION: Includes individually fused output transistors, thermally fused power transformer and double fuses for power line protection.

•EASE OF MAINTENANCE: To minimize maintenance effort, the Sabre 180 features easy access to all internal components, built-in fault isolation and troubleshooting aids.

•MOUNTING FLEXIBILITY: The Sabre 180 is designed to be placed on any suitable table top surface, or it may be secured to the top of an available cart.

•VIDEO TAPE: An instructional video tape is available to aid inservice training.

1.1 PRECAUTIONS

The safe and effective use of electrosurgery is dependent, to a large extent, upon factors under the control of the operator, and not entirely controllable by the design of this equipment. It is important that the instructions supplied with this equipment be read, understood, and followed in order that safety and effectiveness be enhanced.

1.1.1 Precautions in Equipment Preparation

•Visually inspect all accessories before each use to verify the integrity of insulation and the absence of obvious defects.

•The Sabre 180 is equipped to connect two monopolar accessories at one time for the convenience of the surgical staff. Despite the fact that the unit will deliver power to only the commanded electrodes, unused accessories that are connected should be stowed in a safe, insulated place such as a non-conductive holster or test tube. We recommend that accessories not be connected unless it is known that they will be needed.

•This unit is equipped with a hospital grade, 3 prong, power cordset that meets all of the requirements for safe grounding of the unit. The user should verify that the power receptacle which this unit uses is properly grounded and correctly polarized. Do not use ground cheater plugs or extension cords.

•Do not place liquid containers on top of the unit. Wipe spilled liquids off the unit immediately. To preclude inadvertent entry of liquids, do not operate this unit except in its normal position.

•Verify that the return electrode cable is connected to the return electrode connector.

•Do not reuse disposable (single use) accessories.

•Do not use cords as handles; damage to the insulation and increased risk of burns or other injury may result.

•This unit is not supplied with all accessories necessary for the full breadth of electrosurgical applications. Hazardous conditions may result from inappropriate selection, connection or use of accessories. Accessories supplied by CONMED are safe and effective for use with this ESU when used according to their accompanying instructions and further instructions in this manual. For further guidance, refer to "IEC Recognized Electrosurgical Accessories", CONMED catalog number 60-5206-001, supplied with some models, or contact your CONMED representative.

1.1.2 Precautions in Patient Preparation

•Electrosurgery should NEVER be performed in the presence of flammable anesthetics, flammable prep solutions, or in oxygen-enriched environments. The risk of igniting flammable gases or other materials is inherent in electrosurgery and cannot be eliminated by device design. Precautions must be taken to restrict flammable materials and substances from the electrosurgical site, whether they are present in the form of an anesthetic or skin preparation agent, or are produced by natural processes within body cavities, or originate in surgical drapes or other materials. There is a risk of pooling of flammable solutions in body depressions such as the umbilicus and in body cavities, such as the vagina. Any excess fluid pooled in these areas should be removed before the equipment is used. Due to the danger of ignition of endogenous gases, the bowel should be

purged and filled with non-flammable gas prior to abdominal surgery.

•This unit is equipped with the Aspen Return Monitor (A.R.M.) which verifies that the return electrode cable is unbroken and connected to the return electrode and to the electrosurgical unit when in Single Pad mode. It DOES NOT verify that a single pad return electrode is in contact with the patient. When in Dual Foil Pad mode, the A.R.M. confirms that the total resistance is in the expected range. Do not depend solely on the Resistance Indicator in the Dual Foil Pad mode. Proper application and visual inspection are required for safe operation.

•The use and proper placement of a return electrode is a key element in the safe and effective use of electrosurgery in monopolar procedures, particularly in the prevention of burns. Follow directions and recommended practices for the preparation, placement, use, surveillance, and removal of any return electrode supplied for use with this electrosurgical unit.

•Apply the return electrode to a clean-shaven surface of the patient that is thoroughly clean and dry. Avoid placement on scar tissue, bony prominences or other areas where pressure points on small areas might develop.

•Because of the risk of burns, needles should never be used as return electrodes for electrosurgery. Return electrodes should be placed such that as much of their conductive area as possible is in firm contact with an area of the patients' body that has a good blood supply and as close to the operative site as is practical. Adhesive-type return electrodes should be reliably attached with their entire area in contact with the patients' body.

•In general, electrosurgical current paths should be as short as possible and should run either longitudinally or in a diagonal direction to the body, not laterally and under no circumstances lateral to the thorax.

•Electrodes and probes of monitoring, stimulating, and imaging devices can provide paths for high frequency currents even if they are battery powered, insulated or isolated at 60 Hz. The risk of burns can be reduced but not eliminated by placing the electrodes of probes as far away as possible from the electrosurgical site and the return electrode. Protective impedances incorporated in the monitoring leads may further reduce the risk of these burns. Needles should not be used as monitoring electrodes during electrosurgical procedures.

•The active electrode should not be used in the vicinity of electrocardiograph electrodes.

•Heat applied by thermal blankets or other sources is cumulative with the heat produced at the return electrode (caused by electrosurgical currents). Risk of a patient injury may be minimized by choosing a dispersive electrode site that is remote from other heat sources.

•When using injection cannulas as electrocardiograph electrodes, the metal cone must not be placed on the skin; this also applies to the leads to monitoring instruments.

•During the use of this RF isolated output unit, the patient should not be allowed to come in contact with metal parts that are grounded or other conductive surfaces that have an appreciable capacitance to ground. This will minimize the possibility of localized burns resulting from stray electrosurgical currents to the ground.

•Skin to skin contacts, such as between the arm and the body of a patient, should be avoided by the insertion of a cloth.

•The use of electrosurgery on patients with cardiac pacemakers or pacemaker electrodes is potentially hazardous because the pacemaker may be irreparably damaged and/or the high frequency energy of the electrosurgical output may interfere with the action of the pacemaker and ventricular fibrillation may occur. Precautions should be taken to ensure that the patient's well-being is maintained in the event of such interference. We recommend that the Cardiology Department and the manufacturer of the pacemaker be consulted for advice before operating on a patient with a pacemaker. These precautions also apply to operating room personnel with cardiac pacemakers.

•To minimize the possibility of cardiac pacemaker interference, place the return electrode such that the electrosurgical current path is as near orthogonal as possible to the pacer lead.

1.1.3 Precautions in Use

•The use of monopolar electrosurgery on small appendages, as in circumcision or finger surgery, can cause thrombosis and other unintended injury to tissue proximal to the surgical site. Bipolar techniques avoid these complications.

•Apparent low power output or failure of the electrosurgical equipment to function correctly at otherwise normal settings may indicate faulty application of the return electrode, failure of an electrical lead, or excessive accumulation of tissue on the active electrode. Do not increase power output before checking for obvious defects or misapplication. Check for effective contact of the return electrode to the patient anytime that the patient is moved after initial application of the return electrode.

•If a Dual Foil RETURN Alarm is sounded intraoperatively, visually confirm proper return electrode attachment to the patient prior to pressing the Monitor Set Button.

•Electrosurgical leads should not be allowed to contact the patient, staff, or other leads connected to the patient.

•The output power selected should be as low as possible and activation times should be as short as possible for the intended purpose.

•When uncertain of the proper control setting for the power level in a given procedure, start with a low setting and increase as required and/or consult your Conmed representative.

•Observe all caution and warning notices printed on the cover of the unit.

•The staff should never contact electrosurgical electrodes (either active or dispersive) while the RF output of the unit is energized.

•The tips of recently activated accessories may be hot enough to burn the patient or ignite surgical drapes or other flammable material. Place hot accessories in a test tube after use. An alternative is to wait a few seconds after activation for the tip to cool, and then place the accessory into the supplied holster.

•Electrosurgical currents can produce severe electrical interference with or damage to other nearby electronic devices. Physiologic monitors should be equipped with electrosurgical filters and current-limiting devices (RF chokes). Monitoring electrodes should be placed as far as possible from the surgical site. Video endoscopy equipment, especially camera cables, should have adequate and undamaged electrical shielding.

1.1.4 Precautions When Testing or Servicing

•This electrosurgical unit should be tested by qualified maintenance personnel on a periodic basis to ensure proper and safe operation. We suggest examination of the unit at least once a year.

•Refer all servicing to qualified personnel. Your Conmed representative will be happy to assist you in getting your equipment serviced.

•High voltages are developed within the unit that are accessible when the top cover is removed. These voltages are potentially dangerous and should be treated with extreme caution.

•Never remove or install any parts with power on.

•Avoid contact with the output leads when the unit is activated. Periodically inspect the test leads used for the output connections for obvious defects.

•Although this unit will withstand momentary short circuits on the output, prolonged short circuits may damage the unit. Short-circuiting the output should be avoided since it is neither necessary nor desirable.

•Since the clinical use of electrosurgical units is intermittent in nature with duty cycles on the order of 10%, this unit is not designed to operate for extended periods of continuous output. When testing, it is recommended that duty cycles be limited to 50% with maximum activation times of 30 seconds.

•Life of the equipment will be extended by minimizing operating temperature and extreme thermal cycles.

•The heat dissipation capability of the heat sink is severely impaired by activating the Sabre 180 in other than its normal operating position. There are no tests requiring operation in any other position.

•Consult the factory for advice before making any modifications to the unit.

•Ensure that the RUN-RST-CAL switch is set to RUN and that the two top cover screws are tightened before returning the unit to service.

1.2 SPECIFICATIONS

MAINS INPUT REQUIREMENTS:
•Single Phase AC / 48-62 Hz / 200W
•Power Cord: 3 conductor, #18 AWG (1.5mm^2) Cu, CEE22 250V 6A Mains Connector

	MAINS VOLTAGE VRMS			CURRENT ARMS	
CATALOG NO.	RATED	MIN	MAX	MAX	IDLE
60-5800-001	120	104	127	2.4	0.5
60-5800-002	100	90	110	2.9	0.6
60-5800-003	230	208	254	1.3	0.3

MAINS FREQUENCY LEAKAGE:
•Chassis: <100 uA
•Patient: <10 uA

IEC Class 1, Type CF, Defibrillator Proof

RF OUTPUT SPECIFICATIONS:

MODE	MAX. POWER WATTS	RATED LOAD OHMS	CARRIER FREQ. KHz	CREST FACTOR 50% POWER RATED LOAD	MAX. OPEN CIRCUIT VOLTAGE VPP	PULSE REPETITION FREQ. KHz
CUT PURE	100	500	417	1.8	1600	CONTIN.
CUT BLEND 1	65	500	417	2.3	1650	20 KHz
CUT BLEND 2	50	500	417	3.5	1750	20 KHz
MONO. COAG	80	500	540	7.0	6500	33 KHz
BIPOLAR COAG	50	50	1050	2.4	400	20 KHz

RF LEAKAGE: <100 mA, RF ISOLATED

DUTY CYCLE: 15s ON, 30s IDLE
COOLING: Natural convection, no fan

OUTPUT ACCURACY:
•Setting: +/- 10%, +/- 5W to rated load @ rated mains.
•Mains: < 5% over mains voltage range.
•Power Decrease: < 5%, 50W output, 20 sec.

OUTPUT ADJUSTMENT:
•Settings: by digital knob from 0 to maximum in 1 watt steps.
•Display: seven segment digital display of watts to rated load resolved to 1 watt.

ACTIVATION CHARACTERISTICS:
•Activation tone volume adjustable 40-65 dbA via rear panel knob.

MODE	ACTIVATION MEANS	ACTIVATION TONE	COAG MODE
MONO CUT	HAND OR FOOT	520 Hz	EITHER
MONO COAG	HAND OR FOOT	250 Hz	MONOPOLAR
BIPOLAR COAG	FOOT ONLY	250 Hz	BIPOLAR

•Independence: Only the activated accessory will be live. Only one accessory may be activated at a time.
•Control switch activation resistance: < 1000 ohms.

ACCESSORY CONNECTIONS:
•CONMED makes available adapters to permit use of accessories with other than standard connectors:
- •Monopolar Active: 3-pin handswitched and Bovie #12 footswitched.
- •Monopolar Return: 2-pin A.R.M./REM capable.
- •Bipolar: Two 1/4" (6.4mm) banana jacks.
- •Footswitch: 4-pin MS connector for Aspen dual-treadle footswitch.

ALARMS:
•Return Electrode: 1000 Hz, > 65 dbA
- •Single Foil acceptance: 0-10 ohms nominal
- •Dual Foil acceptance: 10-150 ohms nominal
- •Dual Foil alarm threshold: monitor set resistance +20% nominal

•Control error: 1710 Hz pulsating, 40-65 dbA
•Machine fault: 1000 Hz, 65 dbA continuous

DIMENSIONS:
•Size: 6" H (153mm) x 12" W (305mm) x 16" D (407mm)
•Weight: 20 lbs. (9.1 kg)
Note: Allow clearance of 2" (50mm) on each side and 3" (75mm) above for cooling.

SHIPPING & STORAGE:
Prior to shipment or storage, unit should be enclosed and sealed in polyethylene bag and placed in original carton using original packing materials.

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

1.3 OUTPUT CHARACTERISTICS

Figure 1.1 illustrates output power delivered to rated load for all available modes. Section 1.2 specified rated loads and maximum power for each mode, while Figures 1.2-1.6 illustrate output power delivered to a range of load resistances for each mode.

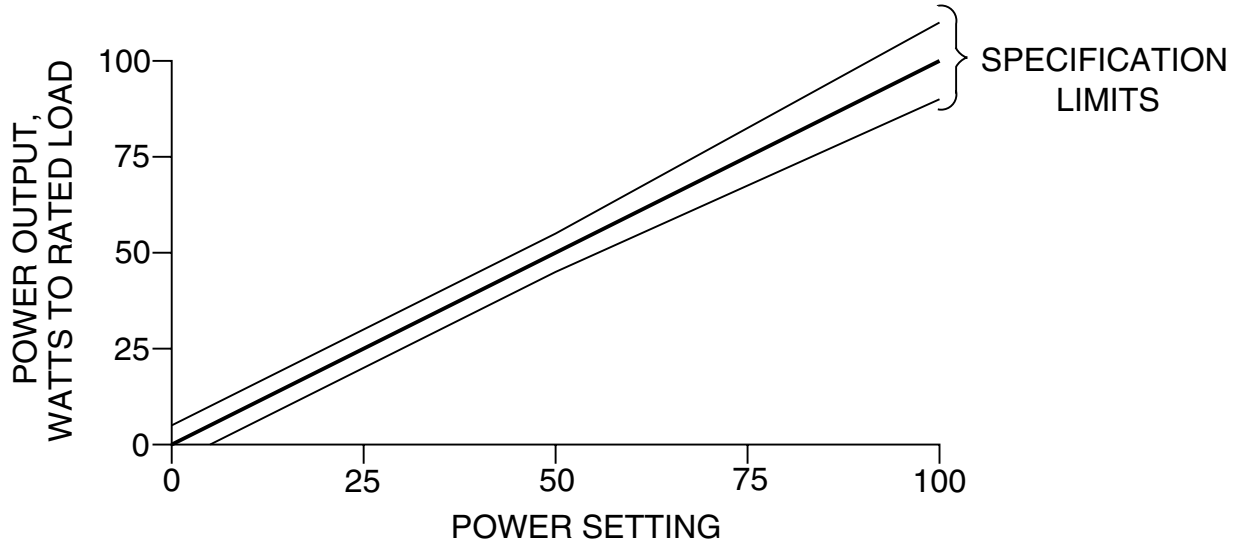


FIGURE 1.1 OUTPUT POWER VS. POWER SETTING

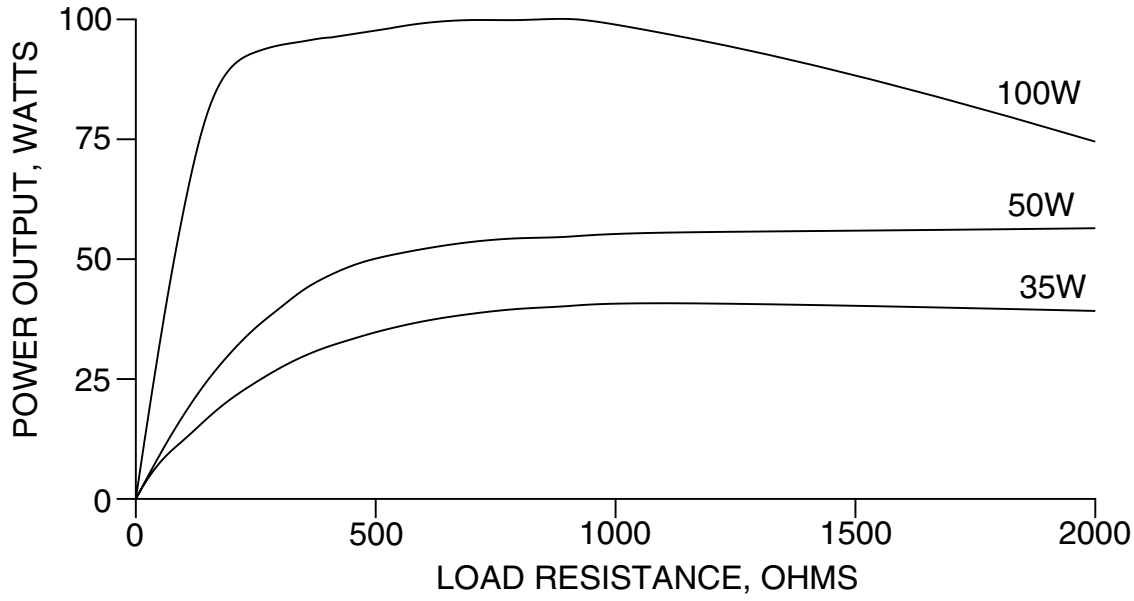


FIGURE 1.2 PURE CUT LOAD REGULATION

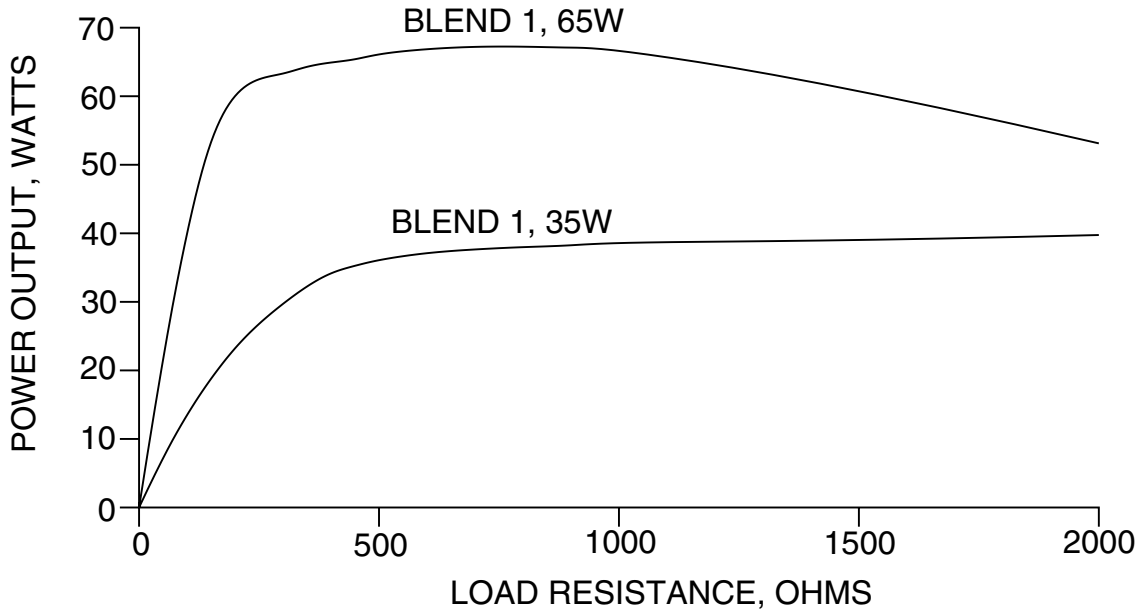


FIGURE 1.3 BLEND 1 CUT LOAD REGULATION

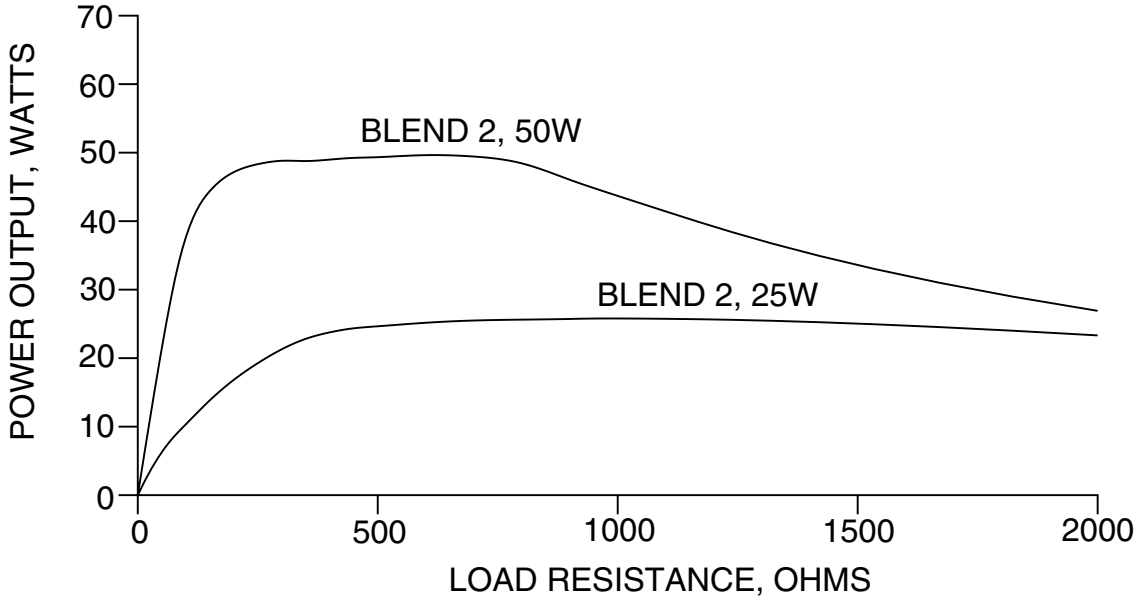


FIGURE 1.4 BLEND 2 CUT LOAD REGULATION

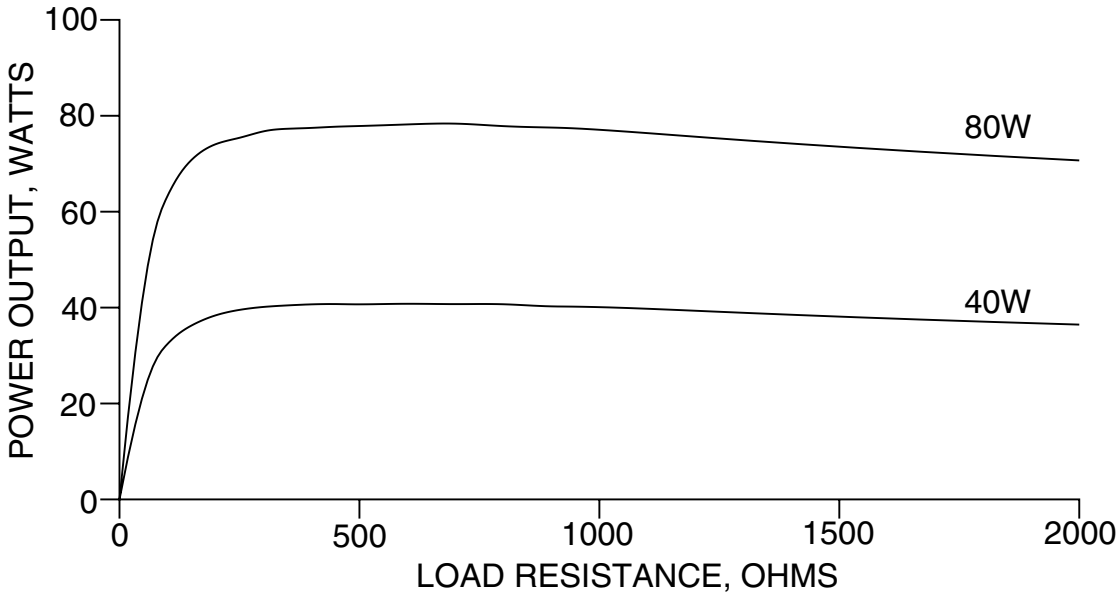


FIGURE 1.5 MONOPOLAR COAG REGULATION

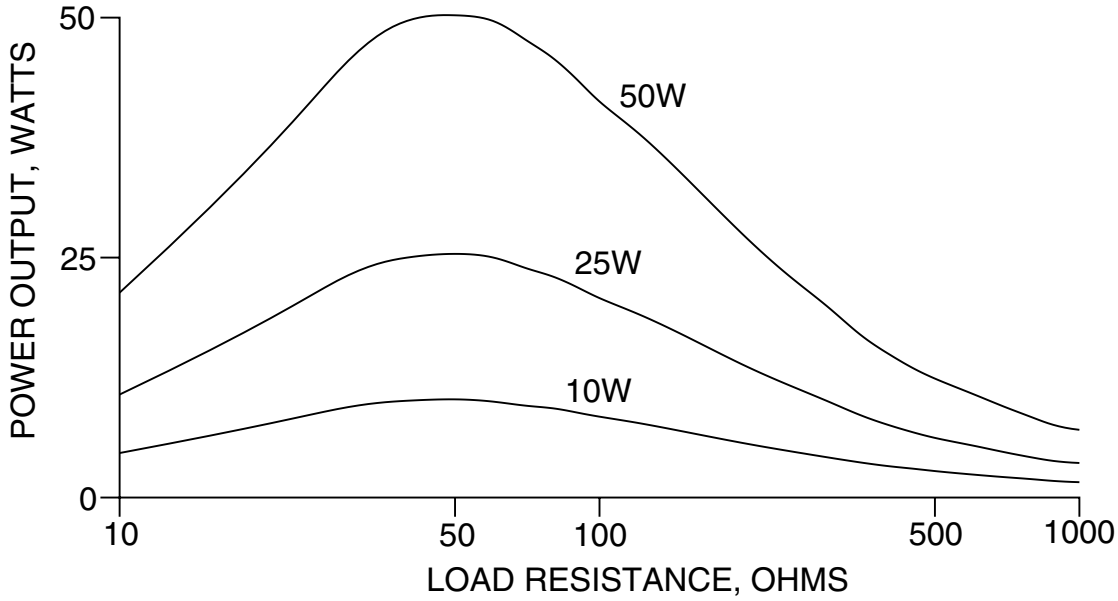


FIGURE 1.6 BIPOLAR COAG REGULATION

1.4 EXPLANATION OF SYMBOLS

CONTROL PANEL

PURE CUT - WAVEFORM WITH MINIMUM THERMAL DAMAGE AND HEMOSTASIS

BLEND 1 - CUT WAVEFORM WITH MODERATE HEMOSTASIS

BLEND 2 - CUT WAVEFORM WITH HEAVY HEMOSTASIS

MONOPOLAR COAGULATION

BIPOLAR COAGULATION

MACHINE FAULT - UNIT HAS DISABLED ITSELF. REFER TO ACCOMPANYING DOCUMENTS

RETURN MONITOR ALARM - MONOPOLAR OUTPUT IS DISABLED

SINGLE FOIL - USED WITH ELECTRODES THAT DO NOT MONITOR CONTACT QUALITY

DUAL FOIL - SETS MONITOR TO USE ELECTRODES THAT DO MONITOR CONTACT QUALITY

RESISTANCE - IN DUAL FOIL MODE, INDICATES RELATIVE RESISTANCE OF RETURN ELECTRODE CONTACT WITH THE PATIENT

TOP COVER

IPX1 DRIP PROOF - ENCLOSURE PROTECTED AGAINST VERTICALLY FALLING WATER DROPS WHEN EQUIPMENT IS IN A POSITION OF NORMAL USE

POWER SWITCH

POWER ON - POWER SWITCH POSITION TO TURN EQUIPMENT ON

POWER OFF - POWER SWITCH POSITION TO TURN EQUIPMENT OFF

THIS EQUIPMENT INTENTIONALLY SUPPLIES NON-IONIZING RF ENERGY FOR PHYSIOLOGICAL EFFECT.

OUTPUT PANEL

HANDSWITCHED OUTPUT - CONNECTION FOR HANDSWITCHED MONOPOLAR ACCESSORIES

FOOTSWITCHED OUTPUT - CONNECTION FOR FOOTSWITCHED MONOPOLAR ACCESSORIES

HIGH VOLTAGE CAUTION - EQUIPMENT HAS HIGH VOLTAGE OUTPUT CAPABLE OF CAUSING PHYSIOLOGICAL EFFECTS

BIPOLAR OUTPUT - CONNECTION FOR BIPOLAR ACCESSORIES

FOOTSWITCHED BIPOLAR OUTPUT

TYPE CF - PATIENT CONNECTIONS ARE ISOLATED FROM EARTH AND RESIST THE EFFECTS OF DEFIBRILLATOR DISCHARGE

RETURN ELECTRODE - CONNECTION FOR MONOPOLAR DISPERSIVE ELECTRODE

RF ISOLATED - PATIENT CONNECTIONS ARE ISOLATED FROM EARTH AT HIGH FREQUENCY

CONSULT ACCOMPANYING DOCUMENTS PRIOR TO PLACING EQUIPMENT IN SERVICE

REAR PANEL

FOOTSWITCH CONNECTOR

ACTIVATION TONE VOLUME

A4 ASSEMBLY

CAUTION - THIS CIRCUITRY SUPPORTS PEAK VOLTAGES GREATER THAN 1000V

PROTECTIVE EARTH (GROUND)

Installation & Operation

Section 2.0

This section contains initial installation, preliminary checks and operating instructions for the Sabre 180.

2.1 INITIAL INSPECTION

Unpack the unit upon receipt and physically inspect it for any obvious damage that may have occurred during shipment. We recommend that this inspection be performed by a qualified biomedical engineer or other person thoroughly familiar with electrosurgical devices. If the unit is found to be damaged, notify the carrier and your Conmed representative immediately. Retain original packing material for future storage or shipment.

2.2 INSTALLATION

The unit may be placed on any stable cart or table.

CAUTION: Since the unit depends on natural convection of air for cooling, it should not be installed in a cabinet or similar enclosure. If mounted on a shelf, allow a two inch clearance on either side and three inches above the unit to permit free circulation of cooling air.

The power cordset of the unit should be connected to a properly polarized and grounded power source whose voltage and frequency characteristics are compatible with those listed on the nameplate of this unit.

2.3 PRELIMINARY CHECKS

Prior to initial use of this unit in clinical service it is recommended that its performance be tested in accordance with the tests described in the Sabre 180 Service Manual. Results of that testing should be compared to the results tabulated on the factory Test Data Sheet that is supplied with each unit. This data should be retained for future reference and comparison.

2.3.1 Preliminary Functional Testing

The following checks are recommended upon initial installation of the equipment and prior to each use of the instrument to avoid unnecessary delays in surgery. See Figures 2.1 - 2.3 for location of controls and connectors.

1. Ensure that the Power Switch is OFF.

2. Connect the power cordset to the unit's mains inlet on the rear panel and to a properly grounded and polarized mating power receptacle.

3. Connect a two-treadle monopolar foot switch to the connector on the rear panel of the unit.

4. Connect a handcontrol (hand-switchable pencil) to the appropriate connector on the output panel.

5. Make no connection to the Dispersive Electrode (Patient Plate) connector at this time.

6. Set the Power Switch to the ON position. Within one second the machine should respond by:

a) Sounding each of the four tones in ascending order over a one second interval.

b) During that interval, displaying "8"s on all five digital displays.

c) Illuminating all mode activation and error indicators and all ten resistance indicator bars.

d) After the fourth tone is complete, the machine should sound two beeps indicating a return fault. Power and mode selections will change to power-up defaults (see Section 2.6.5 for default option selection).

7. Control Panel Checks:

a) Rotate the CUT and COAG power controls CW and CCW at least one revolution (36 steps), verifying that the associated power display changes in one watt steps for each click of its control.

(NOTE: Displays will not decrement below zero or increment above maximum rated power for the selected mode.)

b) Using the MODE pushbuttons, step through each CUT and COAG mode, verifying that the associated mode selection indicator illuminates. Set power to zero in each mode. Leave COAG mode in monopolar.

(NOTE: Units not equipped with the Bipolar option do not have COAG mode controls or indicators).

c) Using the PAD pushbutton, verify that the SINGLE and DUAL indicators toggle back and forth. Verify that the RESISTANCE bar graph is dark in SINGLE mode and that all bars are flashing in DUAL mode. Verify that a "two-beep" alarm sounds after each mode change.

d) Verify that the MACHINE indicator is dark and that the RETURN MONITOR indicator is lit in both SINGLE and DUAL modes.

8. Depress the Cut treadle of the foot switch. The Return Alarm tone should sound and the RETURN lamp should remain lit. While holding the Cut treadle, rotate the Volume Control over its full range and verify that there is no significant change in sound level. Release the Cut footswitch. The tone should stop and the RETURN MONITOR should remain lit.

9. Depress the Coag foot switch. The Return Alarm should sound and the RETURN MONITOR should remain lit.

10. On units equipped with Bipolar, select BIPOLAR COAG. Depress the Coag foot switch. Verify that the Coag indicator illuminates and the Coag activation tone sounds. While depressing the Coag treadle, turn the Coag Power Control clockwise. The power should increase from zero to 5 watts. Turn the Coag Power Control counterclockwise and the power should decrease to zero watts.

11. Release the Coag foot switch. The unit should silence. Then, select MONOPOLAR COAG.

12. Select SINGLE PAD MODE. Connect a non-monitoring dispersive electrode to the Patient Plate connector; verify that the Return lamp and bar graph extinguish.

13. Depress the Cut foot switch. The yellow CUT indicator lamp should illuminate and the Cut tone should sound. While Cut is activated, rotate the VOLUME control (rear panel) over its full range, verifying that the tone volume varies accordingly. Set the volume to a comfortable yet audible level.

(NOTE: At minimum volume, the activation tones should remain audible.)

14. While continuing to press the Cut treadle of the foot switch, depress the Coag treadle. A pulsating alarm tone will sound. Release the Cut treadle, continue to press the Coag treadle and confirm that the sound changes to the Coag tone, and the blue Coag indicator is illuminated until the Coag treadle is also released.

15. Activate, one at a time, the Cut and Coag handswitch controls verifying proper actuation of each mode.

15a. While depressing the Coag treadle (or handswitch), turn the Coag Power Control clockwise. The power should increase from zero to 5 watts. Turn the Coag Power Control counterclockwise and the power should decrease to zero watts.

15b. While depressing the Cut treadle (or handswitch), turn the Cut Power Control clockwise. The power should increase from zero to 5 watts. Turn the Cut Power Control counterclockwise and the power should decrease to zero watts.

16. While the single foil electrode remains connected, select DUAL PAD mode. Verify a

return alarm and that the bar graph remains dark. Press MONITOR SET and verify that RETURN MONITOR remains lit and a "two-beep" alarm sounds.

17. Replace the single foil electrode with an A.R.M. compatible dual-foil monitoring electrode. While the electrode remains open to the air, press MONITOR SET. Verify that RETURN MONITOR remains lit, a two-beep alarm sounds and that all RESISTANCE bar segments are flashing.

18. Gradually apply the dual foil electrode to well-perfused, relatively hair-free skin surface, such as the medial forearm or posterior calf. As electrode contact area increases, verify that the RESISTANCE bar graph segments darken from right to left.

19. With the dual foil electrode fully applied, verify that a portion of the RESISTANCE bar graph remains flashing. Press MONITOR SET, and verify that the RETURN MONITOR goes out and that the RESISTANCE bar graph stops flashing.

20. Gradually peel the dual foil electrode until a RETURN alarm occurs. Verify that over 2/3rd of the electrode remains in contact with the skin at the onset of the alarm. Continue peeling the electrode slowly, verifying the RESISTANCE bar graph progressively illuminates.

2.3.2 Preliminary Performance Testing

After the unit passes the Preliminary Functional Tests of Paragraph 2.3.1, preliminary performance testing may be conducted. Such testing is best carried out by use of an electrosurgical generator tester, as described in Section 4 of the Sabre 180 Service Manual. If such a tester is available, note that the power display will most accurately indicate the power available to a 500 ohm (Monopolar) and the 50 ohm (Bipolar) noninductive resistor. However, the indicated power to any such load in the 300-500 ohm (40-80 Bipolar) range should be within 15% of that indicated on the digital display.

If no tester is convenient, the availability of therapeutic current may be ascertained subjectively by attempting to cut and coagulate on surrogate tissue such as a piece of meat or fresh fruit, a wet bar of soap or a sponge moistened in saline.

Although not recommended, a last resort verification of available power can be made by drawing arcs between active and dispersive electrodes or between the tips of a bipolar forceps. Such a test will not damage the unit if not carried out for more than a few seconds, however one should expect that the electrodes may be damaged due to the extreme temperatures generated by the arc.

2.4 CONTROLS, DISPLAYS AND CONNECTORS

(1) CUT ACTIVATION INDICATOR - Lit when a cutting output is present.

(2) CUT POWER SETTING - Displays power setting of selected cut mode.

(3) COAG ACTIVATION INDICATOR - Lit when monopolar or bipolar coag output is present.

(4) COAG POWER SETTING - Displays power setting of selected coag mode.

(5) MACHINE INDICATOR - Lit when an internal fault has disabled unit. Accompanied by diagnostic code in power setting windows (2), (4).

(6) RETURN MONITOR INDICATOR - Lit when monopolar output is disabled due to a fault in the return electrode circuit.

(7) RESISTANCE BAR GRAPH- Indicates relative resistance at dual foil monitoring return electrode.

(8) MONITOR SET PUSHBUTTON - In dual foil mode, stores present monitor resistance and clears return monitor alarm (6).

(9) PAD SELECTION - Selects whether return monitor is to operate with SINGLE foil (non-monitoring) or DUAL foil (contact quality monitoring) return electrodes.

(10) COAG POWER CONTROL - Adjusts coag power setting (4) of selected coag mode (11). Does not affect the non-selected mode.

(11) COAG MODE SELECTION
•MONOPOLAR - Coag hand or foot switch activates coag output at appropriate monopolar active output.
•BIPOLAR - Coag foot switch activates bipolar output. Cut hand or foot switch will operate as in monopolar mode.

(12) CUT POWER CONTROL - Adjusts cut power setting (2) of selected cut mode (13).

(13) CUT MODE SELECTION - Selects degree of hemostasis of monopolar cut waveform as indicated by associated indicator lamps.(1)

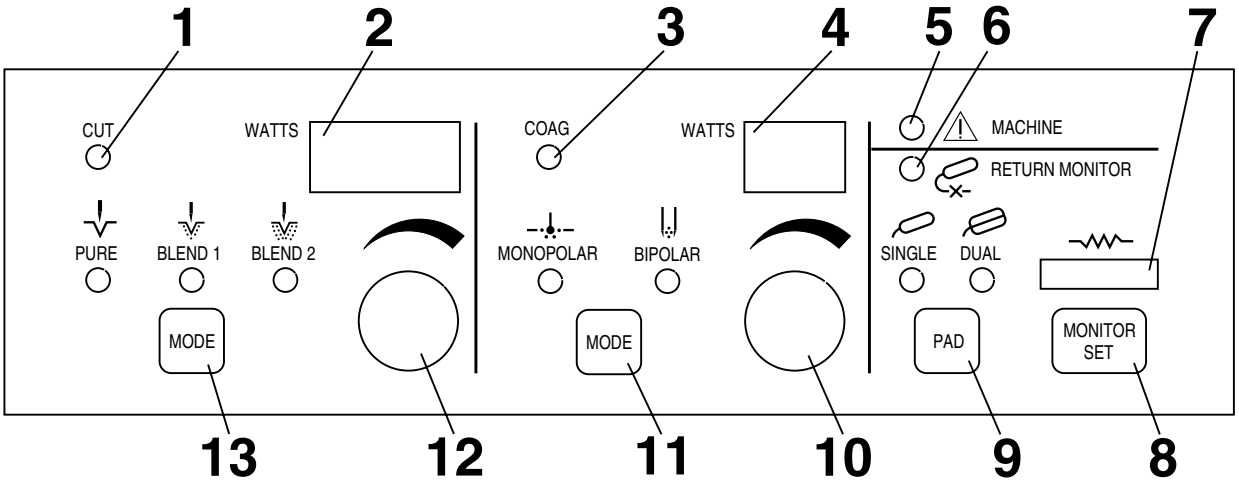


FIGURE 2.1 CONTROL PANEL

(1) HANDSWITCHED MONOPOLAR ACTIVE JACK - Accepts industry-standard handswitching monopolar active accessories. Output is delivered only when handswitch controls are operated. See below for connections.

(2) FOOTSWITCHED MONOPOLAR ACTIVE JACK - Accepts Bovie #12 monopolar active accessories and adapters. Output is delivered only when foot switch is operated.

(3) BIPOLAR OUTPUT - Accepts Conmed bipolar plugs and bipolar cords with 1/4" banana plugs. The small hand switch pin is unused. Output is delivered only in BIPOLAR COAG mode when coag footswitch is depressed.

(4) RETURN ELECTRODE JACK - Accepts Industry standard ARM™ 2-pin dispersive electrode cord plugs. Proper connection is required for monopolar operation.

(5) POWER SWITCH - Controls AC power on (1) and off (O).

(6) RETURN ELECTRODE ADAPTER - Provides for use of CONMED Bioplus single full dispersive electrodes when connected to return electrode jack (4).

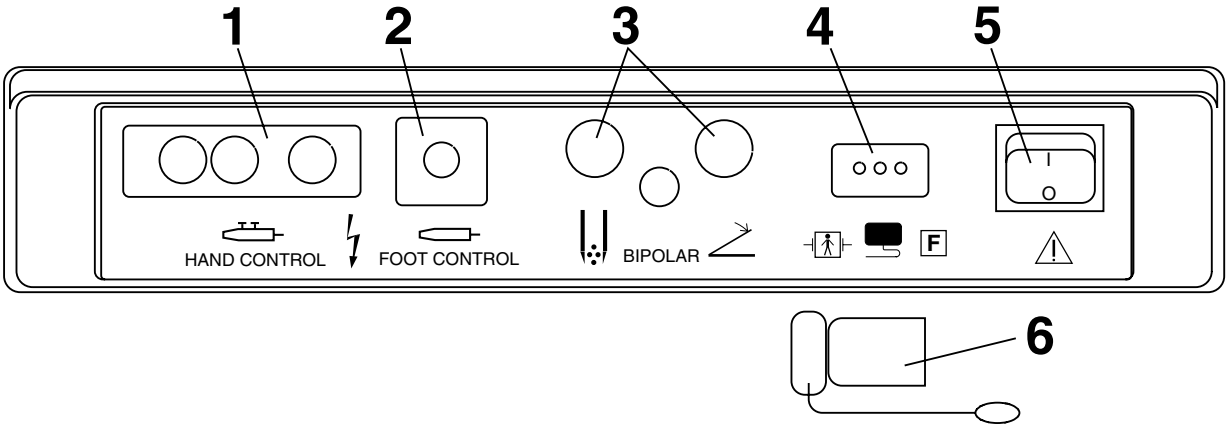
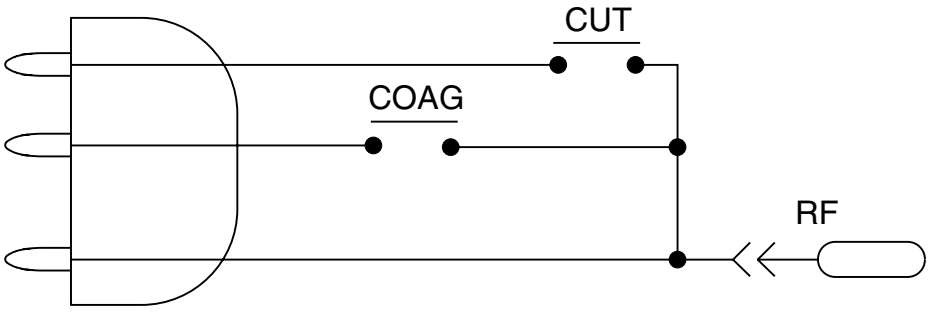


FIGURE 2.2 OUTPUT PANEL



HANDSWITCHED ACTIVE CONNECTIONS

(1) MAINS INLET - Accepts AC power cordset.

(2) MAINS FUSES - Overload protection on AC input.

CAUTION: Replace only with Type T (SLO-BLO) 5 x 20mm fuses with ratings as marked.

(3) FOOT SWITCH CONNECTOR - Accepts Aspen dual treadle foot switch such as Cat. No. 60-5104-001. See below for connections.

(4) VOLUME CONTROL - Sets volume of activation tones over specified range. Does not affect alarm tone volume.

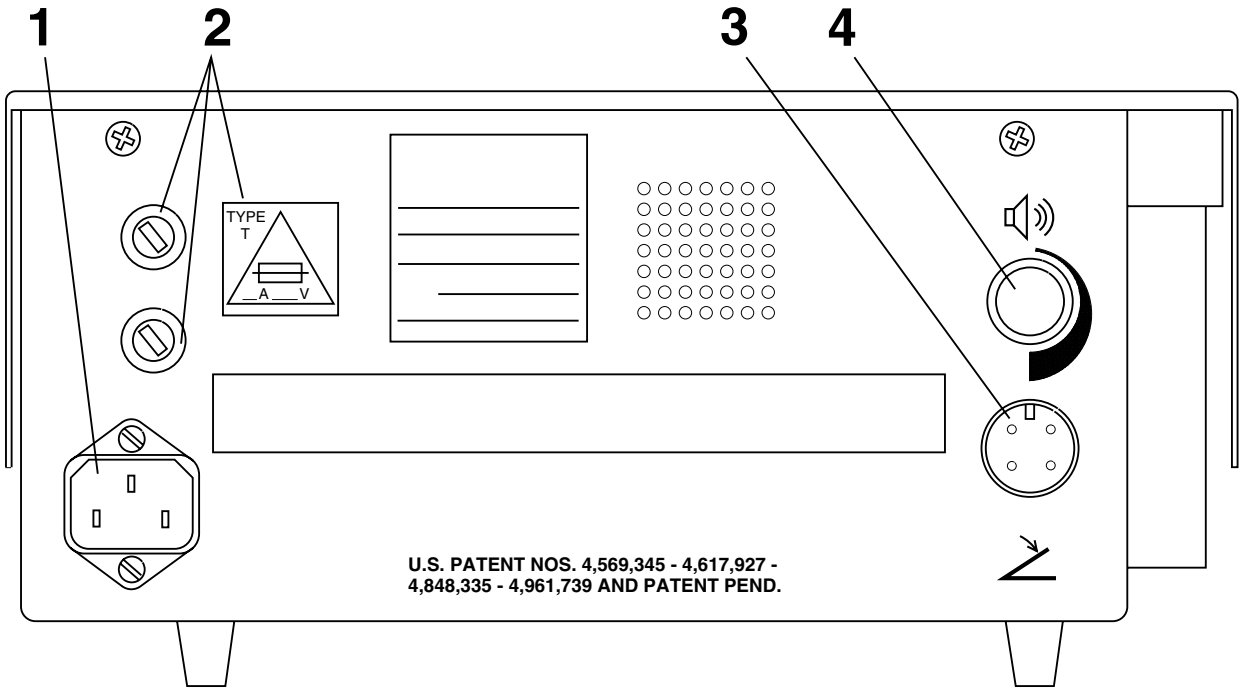
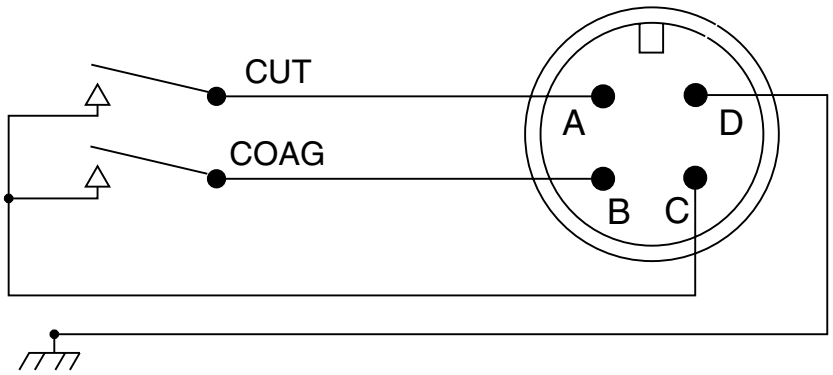


FIGURE 2.3 REAR PANEL



FOOTSWITCH CONNECTIONS

2.5 Operating Instructions

2.5.1 Preliminary Set-Up

1. Ensure the Power Switch is OFF, then connect the power cordset to the unit and to a properly grounded and polarized mating power receptacle. Do not connect a Return electrode at this time.

2. Set the Power Switch to the ON position. Within one second, the machine should respond by:

a) Sounding each of the four tones in ascending order over a 1 second interval.

b) Displaying all "8"s on the digital power displays.

c) Illuminating both activation indicators, all mode indicators, both fault indicators, and all Resistance indicator bars.

d) After the fourth tone is complete, the machine will sound an alarm tone twice, and light the RETURN MONITOR indicator. If the "last used" default option is installed, the controls will return to the settings when last activated. Otherwise, a single zero should appear in each power display. PURE Cut and MONOPOLAR Coag Modes will be illuminated. The last used PAD mode will still appear.

After two seconds, the unit is ready for use. If the unit sounds a continuous high tone, displays MACHINE fault, or otherwise fails to respond as above, the unit has failed one of its internal tests and is not ready for use. Before turning the power off, note any "HLP" code displayed in the power displays to assist in the diagnosis by a biomedical technician.

3. Inspect, then connect the desired monopolar active accessories to the hand controlled or foot switch controlled connectors of the electrosurgical unit.

4. On units equipped with the Bipolar option, connect the desired bipolar accessory to the two blue bipolar banana jacks. Although hand switched bipolar accessories and cords may be used with this unit, they will be activated only using the foot switch.

CAUTION: Always stow unused accessories in a safe, insulated location such as a test tube or holster.

5. Connect the foot switch to the rear of the unit (not required if only hand switchable monopolar accessories are to be used).

6. Inspect, then connect the plug of the dispersive electrode cable to the return electrode jack or to an appropriate adapter. A dispersive electrode need not be connected if only Bipolar operation is required.

NOTE: This electrosurgical unit incorporates the Aspen Return Monitor. The monitor will inhibit Monopolar operation of the unit if its requirements for the return electrode have not been satisfied (see instruction 8).

7. Select and prepare the patient return electrode site and apply the return electrode in accordance with the manufacturer's instructions. If no instructions are given observe the guidelines provided in Section 1.1.2 of this manual.

8. Use the PAD button to select DUAL or SINGLE foil Mode appropriate to the type of return electrode connected. Confirm that the Resistance indicator and Return Fault indicator are blank if SINGLE foil mode is selected. If DUAL foil mode is selected, press the MONITOR Set key. Confirm the Return Fault indicator is blank, and the Resistance indicator stops flashing. The number of bars indicates the patient's resistance and can be used as an indicator of patient risk.

>>>>>>>>>>WARNING<<<<<<<<<
DO NOT DEPEND SOLELY ON THE RESISTANCE INDICATOR FOR CONFIRMATION OF SAFE RETURN ELECTRODE APPLICATION. QUALIFIED PERSONNEL SHOULD MAKE THE FINAL DECISION ON PROPER ELECTRODE PLACEMENT.

9. Set the Cut mode selector to PURE for cutting with minimum hemostasis, BLEND 1 for moderate cutting hemostasis or BLEND 2 for heavy hemostasis. The mode is changed by depressing and releasing the Cut MODE pushbutton. The selected mode is indicated by illumination of the associated indicator.

10. On units with the Bipolar option select the desired Coag mode using the Bipolar mode pushbutton.

11. Adjust the Cut and Coag power controls to the desired settings. If unsure of the proper settings, start the controls at zero or a low value such as 25 for Cut, 30 for Coag and 15 for Bipolar. Note that sections for each mode are independent.

2.5.2 Operation

Activate the electrosurgical unit in the desired operating mode by depressing the appropriate treadle of the foot switch or switch of a hand controlled accessory. On units equipped with the Bipolar option, the coag foot switch will control output to the Bipolar jacks in Bipolar Coag mode, and Monopolar Cut only will remain available at either of the Monopolar active jacks.

Adjust the corresponding power level control until the desired results are obtained. The available power in watts will be displayed in the window above each power control knob. Noting this wattage may be useful in attempting to derive similar surgical effects from units of different manufacturers.

Surgical effects are dependent upon a number of factors including waveform, electrode size, electrode geometry, power level and surgical technique.

The waveform is determined by the mode activated by the user and the Cut Mode selection. Cutting waveforms are generally continuous (PURE) or have moderate crest factors (BLEND). Coagulation waveforms generally have high crest factors. In general, the higher the crest factor the less tendency a waveform will have to cut and the greater its tendency to coagulate. The lowest crest factor waveform, Pure Cut, will induce minimal thermal damage in biopsy samples.

Monopolar active electrode size and geometry are significant in that a large electrode lacking sharp features, e.g., a ball electrode, will have no tendency to cut, independent of the waveform or power level. On the other hand, a small geometry, sharp electrode, such as a needle or wire loop, will have significant propensity to cut simply from mechanical pressure. Therefore, when coagulating with small geometry electrodes, it is advisable to use only coagulation waveforms, use little if any mechanical pressure, and operate with lower power levels.

The Bipolar waveform is essentially identical to that for coagulation, but is delivered at a much lower voltage and is capable of delivering higher current than Monopolar Coag. Bipolar hemostasis is more localized than that in Monopolar, since only the tissue grasped between the forceps tips is affected. This is particularly desirable in vascular and small appendage surgery, where Monopolar current may concentrate in the proximal vessels resulting in undesired electrosurgical effects in tissue remote from the point of application. This easily controlled localization is also of benefit in plastic and neurosurgery.

The power may be adjusted while activated to a maximum of $\pm$ 5 Watts or $\pm$ 25% of the power setting prior to activation, whichever is greater, for all modes.

2.6 USER MAINTENANCE

2.6.1 General Maintenance Information

This section contains information for ordinary upkeep of the Sabre 180. While the unit has been designed and manufactured to high industry standards, it is recommended that periodic inspection and performance testing be performed by a qualified biomedical technician to ensure continued safe and effective operation.

Ease of maintenance was a primary consideration in the design of the Sabre 180. Maintenance features of this unit include built-in fault detection and trouble-shooting aids, circuit simplicity, circuit protection, use of common parts,easy access, no adjustments and computer aided calibration. These features coupled with the warranty, local support, loaner equipment, factory support, toll

free phone service to the factory and available factory training ensure the user of a minimal maintenance cost.

2.6.2 Cleaning

The exterior of the unit may be cleaned by wiping it with a cloth that has been dampened (not dripping) with a mild detergent or glass cleaner.

2.6.3 Periodic Inspection

The Sabre 180 should be visually inspected at least every six months. This inspection should include checks for:

- Damage to the power cord
- Damage to the power plug
- Tightness of the power plug
- Tightness of the power control knobs
- Tightness of the volume control knob
- Proper mating, cleanliness and absence of damage to the patient connectors
- Obvious external or internal damage to the unit
- Accumulation of lint or debris within the unit or heatsink

2.6.4 Periodic Performance Testing

The Sabre 180 should be performance tested at least every year. Each unit is supplied with a serialized Product Test Data Sheet which tabulates the results of the factory tests that were performed on the unit. This data may be used as a reference for subsequent tests and should be made available to the biomedical technician conducting the tests.

2.6.5 Option Selection

The Sabre 180 Electrosurgical Unit is available with three sets of optional configurations:

1. Default settings on power up may be:

- Last used, or those power and mode settings when the unit was last activated. (Factory preset)

- Zero power, pure cut and monopolar coag. The last used pad selection will nonetheless be saved.

2. Mains (AC supply) voltage may be set for nominal 100, 120, 200 or 230V. See Section 1.2 for acceptable mains voltage limits for each of these options. This option may be changed by a qualified biomedical technician according to instructions in the Sabre 180 Service Manual.

3. Bipolar operation allows coagulation to be performed using either monopolar or bipolar techniques. This option is available only from the factory. Contact your Conmed Representative for further information.

The default settings option may be changed quite easily on site with the use of a few simple tools. Contact your Conmed Representative or a qualified biomedical technician.

2.7 IN CASE OF DIFFICULTY

Your Conmed Sabre 180 Electrosurgical unit is designed and manufactured to the highest standards of quality. Conmed expects this unit to provide years of trouble free service; that's why we back it with a two-year warranty.

Occasionally things don't quite meet our expectations, but fortunately most problems can be quickly corrected on the spot without delaying surgery or requiring a service call. This section is a guide to correcting most common problems as well as a guide to symptoms which clearly require trained technical service.

SYMPTOM	POSSIBLE CAUSES
UNIT WILL NOT POWER UP; NO LAMPS, NO TONES:	•Power cord connections. •Damaged cord. •Power outlet dead •Rear panel fuse blown. (If replacement fuse blows, call for service.)
UNIT POWERS UP BUT DISPLAY AND SOUND IS NONSENSE:	•Call for service.
"HLP" CODE APPEARS RIGHT AFTER POWER UP:	
HLP CODE	
1,2	•Call for service (microprocessor failure).
3	•Unit requires calibration service.
4-7	•Call for service (digital logic failure).
8	•Shorted hand switch or footswitch. Disconnect or replace hand or footswitch.
9	•Internal switch set to calibration (CAL) mode.
10,11	•Improper calibration.
12	•Call for service.
13	•Stuck control panel button. Cycle power and allow unit to initialize without switching controls.
"HLP" CODE APPEARS DURING OPERATION:	
HLP CODE	
5	•Possible internal overload. Try cycling power switch before calling service.
12	•Try cycling power switch before calling service (display error).
21	•A.R.M. Circuit fault - call for service.
NORMAL POWER UP, NO ACTIVATION:	•Defective foot switch. •Defective hand switch.
RETURN MONITOR ALARM:	•PAD mode selection incorrect. •Monitor SET not pressed in DUAL mode. •Return electrode not connected. •Defective return electrode. •Dual foil electrode placed on poor site.
NO OUTPUT, BUT ACTIVATION INDICATORS ARE ON:	•Accessory not properly connected. •Handswitched accessory with foot switch activation, or vice versa. •Coag mode not set for expected accessory. •Defective accessory, cable or adapter. •Electrode not fully inserted in pencil. •Return electrode not connected to patient (SINGLE MODE).
LOWER THAN EXPECTED OUTPUT:	•Poor return electrode contact to patient. **WARNING: BURN HAZARD: Correct before continuing or raising output power.** •Incomplete or contaminated contact on cable, accessory, electrode or adapter. (Usually accompanied by audible or visible sparking.)

If the trouble cannot be corrected on site, contact CONMED Technical Service at the toll-free number shown on the inside cover of this manual. Please have the model number and serial number from the rear power nameplate along with a description of the problem, including power settings, accessories, in use, etc.

Our staff will ensure that your problem is corrected as quickly and painlessly as possible.

Theory of Operation

Section 3.0

3.1 FUNCTIONAL DESCRIPTION

The Functional Block Diagram appears in Figure 5.3. This diagram illustrates the functional partitioning of the unit. Each block defines a major function along with the reference designator(s) of the component(s) that serve primary roles in implementing the function. Dashed lines enclose major assemblies (A-) for cross-referencing to the Interconnect Diagram or Assembly Schematics in Section 5.

The relationships among each block are described by the signals that interconnect them. Narrow lines represent individual signals and are marked with the same signal mnemonics used in the schematics.

Broad lines denote busses, or groups of signals which together serve a common function. To avoid clutter, busses are not necessarily marked with signal mnemonics. Where a bus contains signals all bearing a common mnemonic form, the characters common to all of the mnemonics are shown, with XXs denoting characters which differ among the signal names. For example, the bus marked /FXX contains the signals named /FCT and /FCG. These refer to the foot switch activation signals for Cut and Coag respectively.

Arrowheads describe the direction of signal flow. Most signals are generated at a single source and have one or more destinations. An exception is the Data Bus on the A3 Controller PWB. This bus is bidirectional in that signals may travel either direction from any one of a number of sources. However, only one source may be active at a given time. That source is determined by the Microprocessor which drives the proper signal states out on the Address and Control busses.

Power supply and distribution are not shown in the Functional Block Diagram. This information, along with further detail regarding the circuitry shown in Fig. 5.4 is discussed in Sect. 3.7.

3.2 RF OUTPUT SECTION

Refer to Figure 5.7 for the schematic diagram. This section is located on the forward end of the A4 Power PWB. Its purpose is to isolate the patient-connected circuitry from earth while delivering RF output power, monitoring the return contact quality and activation switch closures.

3.2.1 RF Output Coupling

RF output power may be supplied through one of two RF isolation transformers, as selected by the Bipolar relay, A4K3. When de-energized, K3 connects the power amplifier collector bus to the Monopolar output transformer, T3, which is resonated by C60 and C61 and damped by R100. The main secondary of T3 is capacitively coupled by C69 and C70 to the patient plate output jack and via high-voltage reed relays, to the user selected monopolar active accessory connectors. An auxiliary single-turn T3 secondary supplies a replica of the power amplifier collector voltage to the VSENSE circuit. This rectifies and peak-detects this signal for use by the control circuitry to limit output voltage in Cut.

When K3 is energized, it disconnects T3 and supplies the Bipolar output transformer, T1, with power from the power amplifier. The primary of T1 is resonated by C62 and is damped by R100. This transformer is designed to meet the particular requirements of bipolar electrosurgery which is characterized by much lower impedances and permissible voltages than those in monopolar operation. Its secondary is capacitively coupled to the appropriate output connectors. Output waveforms under various conditions are shown in Figure 3.1.

CAUTION: Because of the high peak-to-peak amplitudes of these waveforms, use oscilloscope probes that can withstand 2 KVpp minimum for cut, 12.0 KVpp minimum for coag, and 500 Vpp minimum for bipolar.

3.2.2 Aspen Return Monitor (A.R.M.) Circuitry and Software

The A.R.M. Circuit converts the electrical resistance appearing in the return electrode circuit into a digital value which can be processed by the microprocessor A3U3. Software processes use this value in conjunction with the PAD SELECT and MONITOR SET buttons to determine when a return fault condition exists. The Resistance Bargraph is also driven by software to indicate the value of the measured DUAL FOIL resistance in the 10 to 150 ohm range.

Resistance Bargraph BARS	Typical Midrange Resistance
0	<10
2	18
3	31
4	43
5	60
6	83
7	118
8	145
10	>150

TABLE 3.1

Portions of this function are implemented on the A3 Controller PWB, Figure 5.6b and on the A4 Output PWB, Figure 5.7b.

The A.R.M. circuitry on the A4 PWB comprises an oscillator section and an isolation section. The isolation section employs a shielded toroidal transformer, T5, to couple the impedance presented at return electrode plate jacks, A5J4 to the A.R.M. oscillator, while isolating that circuit from the effects of applied RF electrosurgical current and voltage. Capacitors C71 and 72 split the return current evenly between the two legs, thus minimizing the RF voltage appearing across T5 windings. T5 also acts to step up the return circuit impedance by about 10:1. The shield serves to prevent the RF stray magnetic field generated by the monopolar output transformer, T3, from interfering with the A.R.M. circuitry during RF activation.

The A.R.M. oscillator generates a low-power sinewave voltage of about 37 KHz. This frequency is determined by the inductance of T4 in parallel with the capacitance presented by C33-34. Transistors Q5 and Q6 are cross-coupled via R19 and R20, so that when one transistor is conducting, the other is fully turned off due to lack of base drive. The conducting transistor turns off at the next zero-crossing of the sinusoidal voltage on the primary of T4. This allows its collector voltage to rise and thus provide base current to the other transistor to turn it on. Figure 3.2 shows typical A.R.M. oscillator waveforms with a 50-ohm return circuit resistance applied.

The A.R.M. oscillator is powered by a constant 0.5 mA dc current driven from the A3 PWB via the VARM signal line. This current feeds into the center tap of T4 primary. The voltage on the center tap is the average of the two collector voltages so it appears as a full-wave rectified sine wave with a peak amplitude of one-half that on either collector. Inductor L2 helps hold the current fed to T4 constant regardless of these voltage variations, while C59 serves as a bypass to limit the noise conducted from the A5 PWB up the VARM line to the A3 PWB.

Figure 3.1 RF Output Waveforms

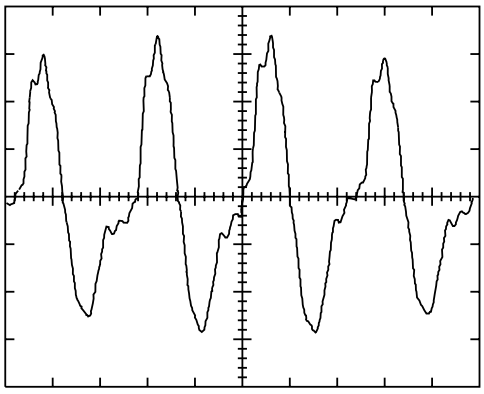


PHOTO 1
Monopolar Pure, 100W, O.C.
200V/div, 1uS/div

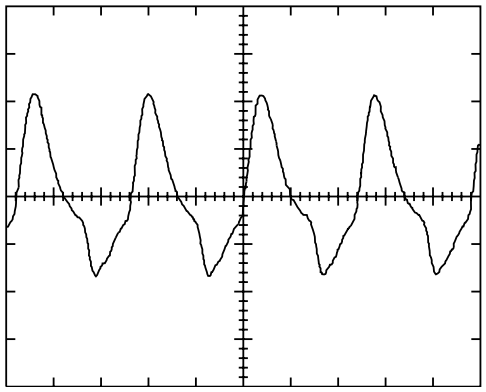


PHOTO 2
Monopolar Pure, 100W, 500 ohm
200V/div, 1uS/div

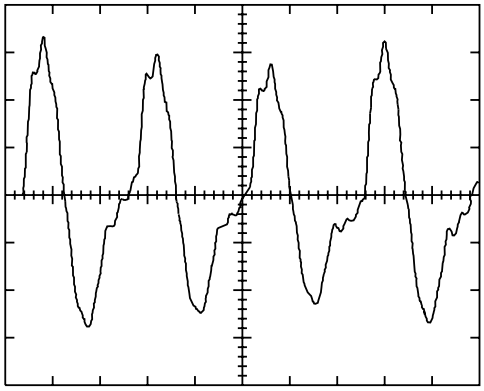


PHOTO 3
Monopolar Pure Cut, 50W, O.C.
200V/div, 1uS/div

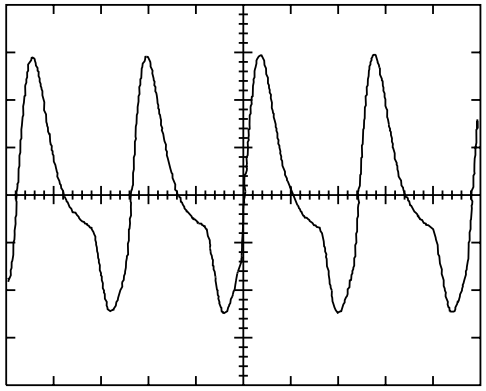


PHOTO 4
Monopolar Pure Cut, 50W, 500 ohm
100V/div, 1uS/div

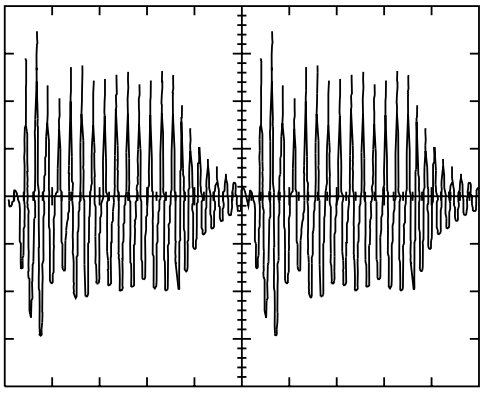


PHOTO 5
Monopolar Blend 1, 65W, O.C.
200V/div, 10uS/div

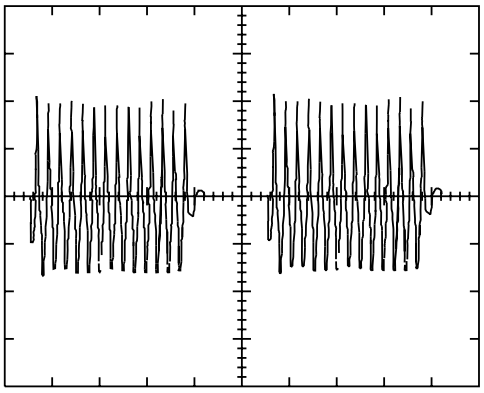


PHOTO 6
Monopolar Blend 1, 65W, 500 ohm
100V/div, 10uS/div

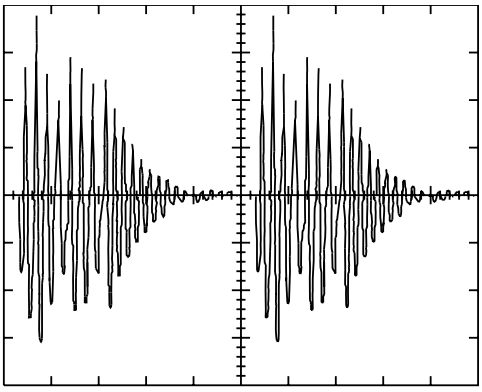


PHOTO 7
Monopolar Blend 2, 50W, O.C.
200V/div, 10uS/div

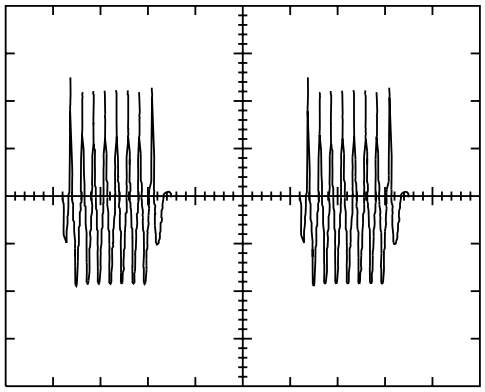


PHOTO 8
Monopolar Blend 2, 50W, 500 ohm
200V/div, 10uS/div

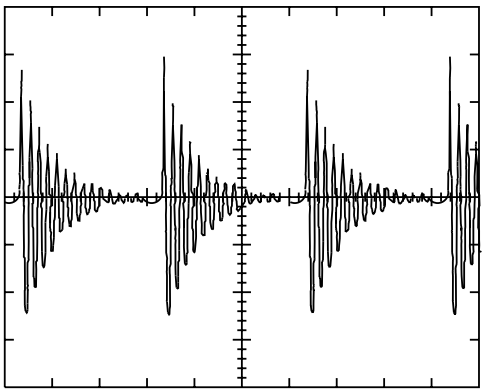


PHOTO 9
Monopolar Coag, 80W, O.C.
1000V/div, 10uS/div

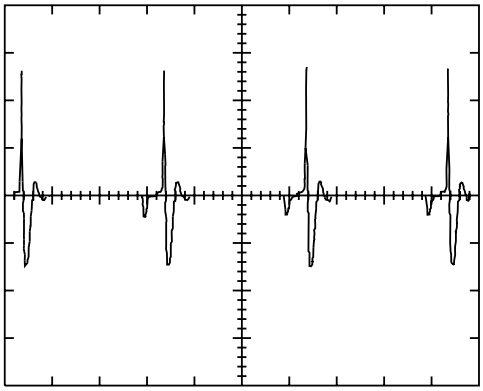


PHOTO 10
Monopolar Coag, 80W, 500 ohm
500V/div, 10uS/div

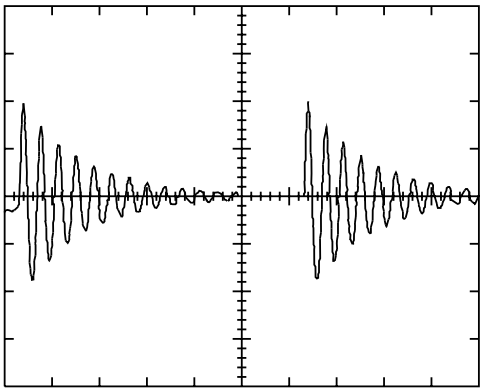


PHOTO 11
Monopolar Coag, 40W, O.C.
1000V/div, 5uS/div

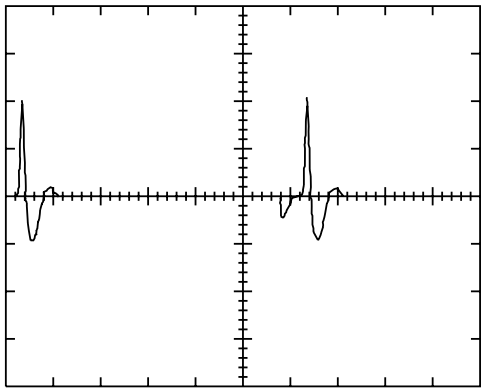


PHOTO 12
Monopolar Coag 40W, 500 ohm
500V/div, 5uS/div

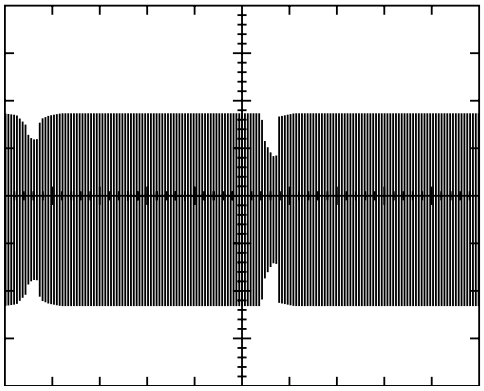


PHOTO 13
Bipolar, 50W, O.C.
100V/div, 10uS/div

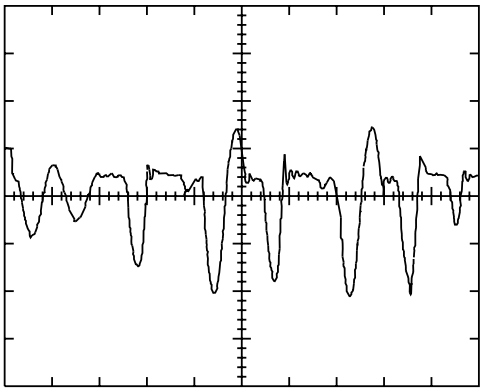


PHOTO 14
Bipolar 50W, O.C., Expanded Scale
100V/div, 1uS/div

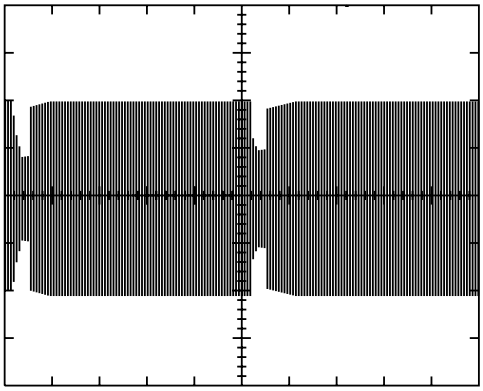


PHOTO 15
Bipolar, 50W, 50 ohm
50V/div, 10uS/div

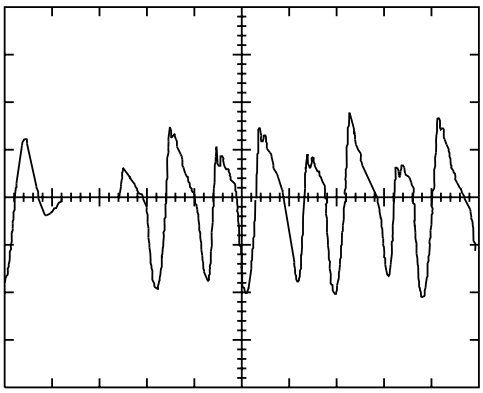


PHOTO 16
Bipolar 50W, 50 ohm, Expanded Scale
50V/div, 1uS/div

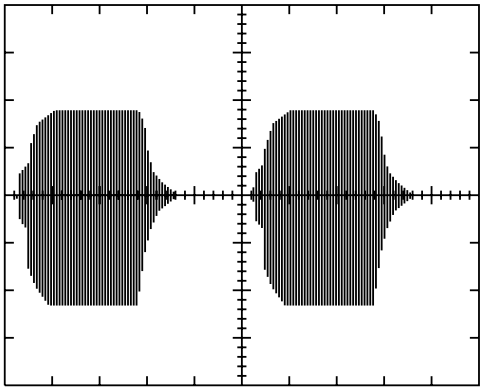


PHOTO 17
Bipolar, 25W, O.C.
100V/div, 10uS/div

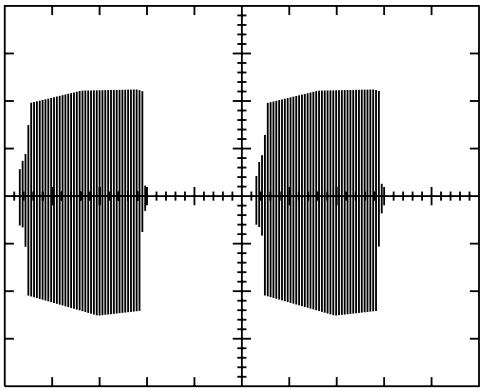


PHOTO 18
Bipolar, 25W, 50 ohm
50V/div, 10uS/div

The A.R.M. oscillator is a dc-to-ac power converter, with its major losses appearing as resistors in parallel with the resistance of the return electrode circuit, R_L transformed up through T4 and T5. In effect, the A.R.M. oscillator transforms R_L into an equivalent dc resistance, Rin , appearing at the VARM input to the circuit. Thus when R_L is very high, as when no connection is made to the Return electrode jacks, Rin is maximum, allowing the VARM voltage to rise to +2.3 - 3.0 Vdc.

When R_L falls into the 10 to 150 ohm range normally encountered with a properly applied dual-foil electrode, Rin also drops and VARM falls into the 1.0 to 2.5 V range. If R_L is very low, as when a single foil electrode is connected, VARM drops to about +0.8 Vdc. Resistors R33 and R34 serve to set a lower limit to the resistance applied across T4's secondary. Without this lower limit, the effective short circuit presented by a single foil return electrode would reduce the Q of the 37 KHz turned circuit to the point that the oscillator would behave erratically. Thus VARM varies directly with the resistance appearing in the return electrode circuit. The relationship is essentially logarithmic, with increases in VARM becoming vanishingly small as R_L rises above 1000 ohms. This means that VARM will change by a nearly constant voltage for a given percentage change in R_L anywhere in the 10 to 150 ohms range.

The balance of the A.R.M. Circuitry resides on the A3 Controller PWB, Figure 5.6b. Diode VR2 is a +1.235 V regulator whose output voltage appears across the 2.49K resistor R47, thus driving a constant current of 0.5 mA into the VARM line. R48 allows the circuit to operate to ground, while R40 and C38 act as a low-pass noise filter. The voltage BVARM at U21-8 is essentially equal to VARM, since that opamp is connected as a high-input-impedance voltage follower.

The digital-to-analog converter, DAC U19, is driven by the microprocessor to produce 0.0 to +2.55 Vdc at U19-16. This voltage is compared to BVARM by comparator U23 to drive ARMCOMP at U23-13. Every 12 msec, the microprocessor reads the ARMCOMP line in response to a sequence of DAC voltages, determined by a successive approximation algorithm, to measure the VARM voltage to a precision of 10mV. This value is then processed along with the VARM values for 10 and 150 ohm return circuit resistances stored in the NOVRAM during the last Pad Calibration to evaluate the current R_L.

The Return Fault process works on a 50-point (0.6 sec) average VARM value. If Single Foil Mode is selected, the microprocessor will declare a Return Fault when VARM indicates that R_L is 10 ohms or greater. The Resistance Bargraph is always dark in this mode.

In Dual Foil Mode, the Resistance Bargraph will be illuminated to indicate R_L in the range of 10 to 150 ohms. At just over 10 ohms, the two left bars are illuminated. As VARM increases, additional bars are illuminated in proportion to VARM, progressing to the right, until R_L approaches 150 ohms, where eight bars are illuminated. When R_L exceeds 150 ohms, all ten bars are illuminated. Whenever a Return Fault condition exists, all illuminated bars will flash, but R_L is still displayed as above. Table 3.1 illustrates the relationship between R_L and the Resistance Bargraph bars.

In Dual Foil Mode, the microprocessor declares a Return Fault if R_L is less than 10 ohms or greater than 150 ohms. If VARM is within the allowed range, then the Return Fault Indicator will turn off when the Monitor Set Key is pressed, and the present value of VARM is stored for reference. A new Return Fault will be declared if R_L rises about 20% above this stored value or goes out of the allowed range.

A rise of approximately 20% over the resistance of a Return electrode in full contact with a patient indicates significant electrode detachment. A Return Fault declared in this case will NOT automatically be cleared if the patient resistance drops back to near the stored value.

The Monitor Set Key must again be pressed to register the staff's satisfaction that the electrode attachment is safe before turning off the alarm.

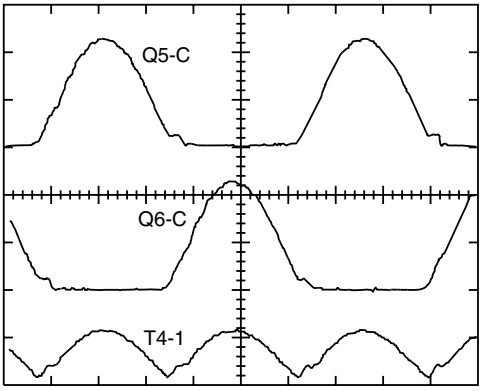


Figure 3.2 A.R.M Oscillator Waveforms
R_L = 50 ohms, 2V/div, 5uS/div

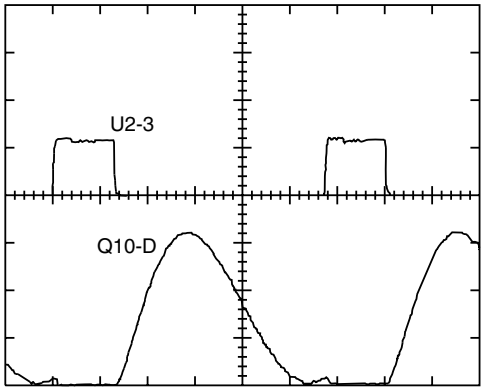


Figure 3.3 Continuity Detector Waveforms
10V/div, 2uS/div

Because patients' and return site resistances vary over a considerable range, it is not safe to assume that any in-range resistance indicates safe electrode attachment. For example, a poorly placed electrode on a well-perfused site can show the same resistance as a safely attached electrode on adipose tissue. Yet the poorly placed electrode could still result in a burn due to low contact area. The clinical staff is responsible for the final judgement of safe return electrode placement.

The unit powers up in whichever pad mode was last used and the Return Fault is ON awaiting a new set point. The Return Fault will also be lit whenever Dual Foil is selected after being in Single Foil Mode. This prevents a poor single foil contact from being mistaken for a good dual foil contact. Normal single foil electrode resistance is well below the range acceptable for dual foil operation.

3.2.3 Continuity Detector

The Continuity Detector provides footswitch and hand switch isolation by both magnetic and optical coupling. Figure 5.7b includes a schematic of the continuity detector. A 90 KHz oscillator, A4U2 generates a 20% duty-cycle rectangular wave drive to FET A4Q10, which drives the resonant primary circuit of a toroidal isolation transformer, T2. Figure 3.3 shows typical waveforms in the Continuity Detector Isolated Power circuitry. The energy coupled to the secondary windings is rectified and filtered to produce an isolated 3 to 4 Vdc source for hand switch and foot switch isolation circuitry. The Monopolar hand Cut switch continuity detector will be used as an example, since all sections are identical. When this switch is closed, dc current limited by R63 sets the emitter voltage of Q14. If the switch resistance is less than about 400 ohms, Q14 will draw base current via voltage divider R60-61. The corresponding collector current flows through the LED in optical isolator U5. This produces a beam of light which falls on U5 phototransistor causing it to draw collector current. This current pulls the signal line /H1CT to a low voltage, and this state is interpreted by the microprocessor as a closure of the switch. When the hand switch is released, Q14 emitter voltage is pulled high, causing Q14 to turn off.

The LED goes dark causing the phototransistor to cease conduction and allow the signal line to be pulled to a high state by resistor network A3RN1. C68 bypasses any RF currents around the accessory switch than may occur due to reverse accessory connection while blocking dc from the Q1 emitter when the accessory switch is open.

3.3 POWER AMPLIFIER

The Power Amplifier (PA) is a hybrid cascode amplifier made of high voltage bipolar transistors and low voltage power MOSFETs. The schematic for this section is included in Figure 5.7a. Figure 3.4 shows the basic hybrid cascode amplifier configuration. The combination of Q1 and Q2 make up a fast, high-voltage amplifier that can be controlled by the combination of the dc voltage VBASE, and the fixed amplitude, variable pulse width signal, VGATE.

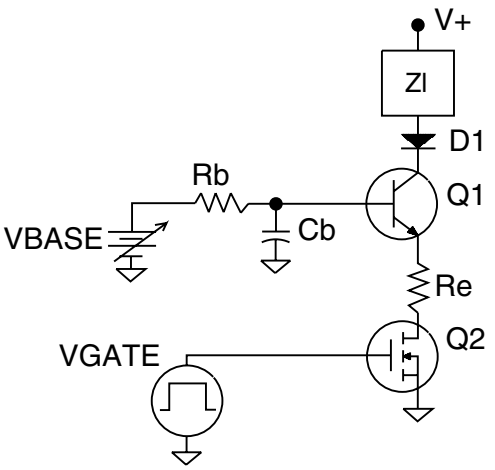


Figure 3.4 Basic Hybrid Cascode Configuration

In the OFF condition, VGATE is near ground, turning off Q2 so that no drain current can flow. Thus no base or emitter current can flow in the bipolar transistor. Since V+ is always greater than VBASE, the collector base junction is reverse-biased, so no collector current will flow and no power is delivered to the load. Turn-on commences with VGATE rising rapidly to about +10V. This results in a large pulse of base current flowing in Q1 from Cb, quickly turning Q1 on which delivers power to Z1. After the turn-on transient, Q2 will be conducting hard and Q1

will draw collector current in proportion to its base current, which in turn is controlled by VBASE and Rb. At sufficiently high base current, Q1 saturates (collector-base voltage nearly zero), transferring maximum available power to Z1 while Q1 and Q2 dissipate little power due to the low voltage across them. Turn-off commences with VGATE quickly dropping to nearly 0 V, shutting off Q2 and effectively disconnecting Q1s emitter from the circuit. Collector current then flows out of Q1s base pin into Cb until all of the charge stored in Q1 during turn-on is washed out. Then Q1 completely shuts off, ceasing power transfer to Z1.

The collector voltage may rise to many times the value of V+ after turn off. Since the emitter is now disconnected, the collector-base voltage can take on the highest value which that junction will sustain with little chance of second-breakdown. The base bypass capacitor, Cb, is sized to ensure that it can absorb all of the stored turn-off charge without allowing Q2s drain voltage to approach its breakdown limit. Further, this charge is now available to charge the base on the next cycle, thereby significantly reducing the net current drain from the VBASE supply.

The saturated operation described above takes place in both Monopolar Coag and during high-power (>60W) Cut. During the latter mode, power increases take place because the dynamics of Z1 allow Q1 to saturate over a greater proportion of the conduction cycle as VBASE is increased. Once saturation occurs, excess stored charge accumulates, extending the time required to remove the charge on turn-off and effectively increasing the duty cycle of the amplifier. At lower Cut power settings, VBASE is too low to allow saturation, so Q1 conducts only partially, absorbing some of the power that could otherwise be supplied to Z1. This mode is not as efficient as saturated operation because Q1 sees simultaneous voltage and current. However, the current at this point is low enough to limit Q1's dissipation to that which can be dissipated by the heatsink without excessive junction temperature rise. When VBASE drops to below about 0.6 V, no power is delivered to the load since this voltage is too low to cause base current to flow.

The PA consists of a single power MOSFET driving the emitters of three bipolar transistors. Each bipolar base has its own bypass capacitor and is driven from a common VBASE supply. Each collector and each base is separately fused, allowing a failed part to disconnect itself from the circuit without seriously affecting performance. Failure of a single bipolar transistor will reduce the RF power available by about half, since the other devices will continue to operate.

Voltage snubbing networks protect GATE, VBASE, and the power MOSFET drain from being damaged in the event of any transistor failure. This limits the extent of failure damage. Each collector is equipped with a diode which allows the voltage on the output bus to swing negative with respect to ground, as it does in all monopolar modes of operation at sufficiently high power and load resistance.

In Cut modes, GATE is a fixed frequency rectangular pulse and VBASE is varied from about 0.3 to +8.5 Vdc to control output power. The same is true in Blend except that GATE is further modulated to produce dead time with no output. In Monopolar Coag, VBASE is fixed while GATE is varied in length. This variation in conduction time controls the amount of energy stored in the inductive part of Z1 every cycle and therefore varies the output power level. Bipolar Coag Mode uses a fixed VBASE and varies the number of pulses per cycle period to control output power. See Figure 3.5 for representative GATE drive waveforms.

Figure 3.5 RF Power Amplifier Waveforms

The following waveforms are representative of those which appear in the Sabre 180 Power Amplifier at A4Q7-C, the collector bus COLL (A4TP16) and the FET GATE (A4TP9).

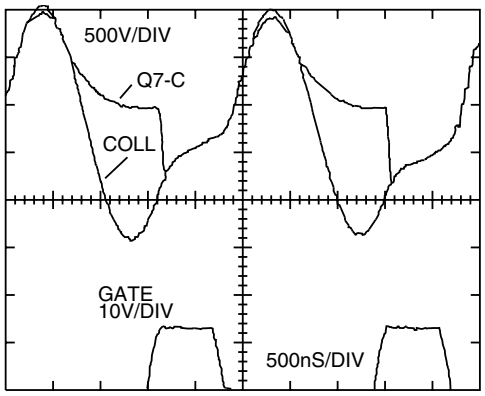


Figure 3.5a
Pure Cut, 100W, Open Circuit

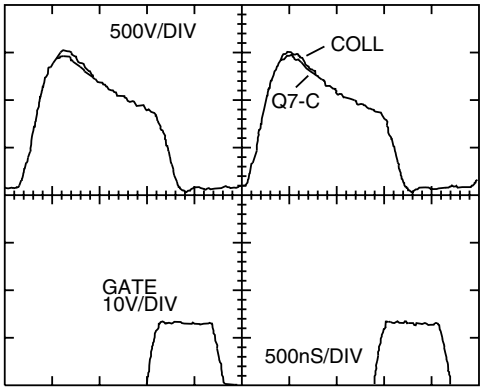


Figure 3.5b
Pure Cut, 100W, 500 ohm

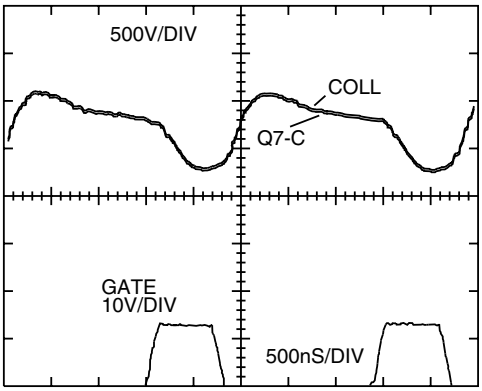


Figure 3.5c
Pure Cut, 25W, 500 ohm

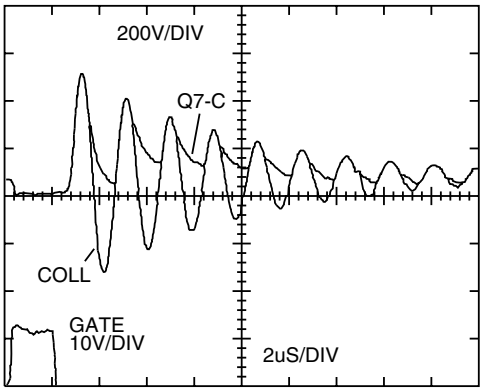


Figure 3.5d
Monopolar Coag, 40W, Open Circuit

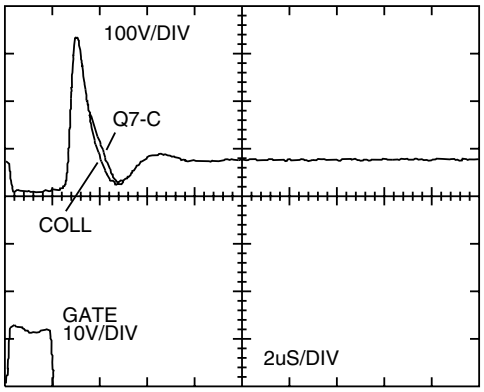


Figure 3.5e
Monopolar Coag, 40W, 500 ohm

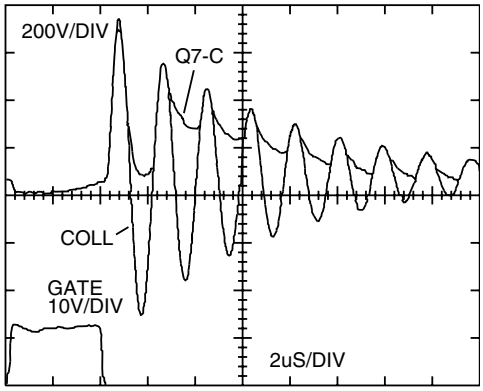


Figure 3.5f
Monopolar Coag, 80W, Open Circuit

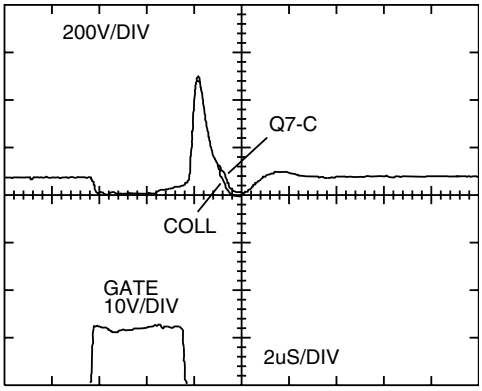


Figure 3.5g
Monopolar Coag, 80W, 500 ohm

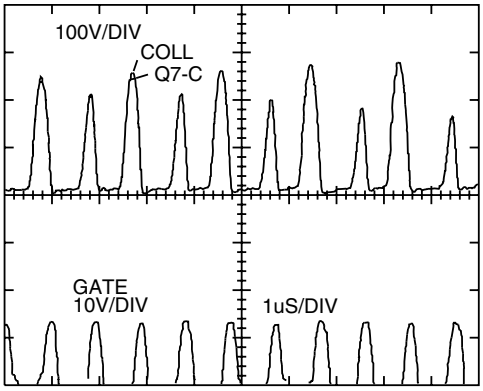


Figure 3.5h
Bipolar Coag, 25W, 50 ohm

3.4 CONTROLLER HARDWARE

The Controller PWB Assembly is based on the 8031, a single chip, 8-bit microprocessor which utilizes external program memory. Refer to schematic, Figure 5.6a. This controller has the following features.

1. Four 8-bit Ports (0,1,2,3) which are individually addressable as 32 Input/Output (I/O) lines.

2. Two 16-bit timer/event counters, one of which is used as a software controlled tone generator via the serial transmit pin TXD (U3 Pin 11).

3. Thirty-two (32)K bytes of externally addressable program memory (A3U1), 128 bytes of nonvolatile RAM (A3U2) for storage of calibration tables, and 256 bytes of serial EEPROM (A2U4) for saving last used control settings.

4. One-chip oscillator and clock circuit which is connected to an external 10 MHz clock signal derived from a 20 MHz quartz time base (A3Y1).

5. One hundred and twenty-eight (128) bytes of internal RAM used as a "scratch pad" by the processor.

The remainder of the controller circuitry consists of the Watchdog Timer (WDT), Power On Reset (POR), Address Decoder, Peripheral Interface Adapter (PIA), Base Voltage Generator (BVG), Current Sensing Circuit, Waveform Generator (WFG), Tone Generator, and the Aspen Return Monitor (A.R.M.) DAC and current source.

The A3 Controller PWB is used for the SABRE 180 and Excalibur ESUs. The PWB is adapted for each unit by installation of the appropriate ROMS, Jumper TP20 and JMP1.

3.4.1 Watchdog Timer (WDT)

The function of this circuit is to monitor the microprocessor for a failure that would cause unpredictable results. During normal operation, the microprocessor program executes in a known sequence. If a software error is detected, an internal interrupt is generated which halts the operation of the microprocessor. If there is a hardware failure sensed by software control, program execution will again be terminated.

Should a failure occur in the CPU that prevents the detection of a problem, thus allowing program execution in a random manner, the Sabre 180 is designed so that the WDT detects the problem. The WDT shuts down the malfunctioning unit to minimize the effects of the failure. This is accomplished by requiring the microprocessor to write to the WDT once during each program execution cycle. This write pulse is referred to as the Watchdog Timer Strobe (WDTSTB). Each cycle is 12 +/- 0.8 milliseconds long. The WDT circuit must hear from the microprocessor within a 10 to 15 msec window. If the WDTSTB occurs early because the program "skipped" a portion of the software or late because it was "hung" in a program loop, the following results:

1. The circuit latches in the failed condition so that further strobing from the microprocessor cannot clear the previous failure.

2. An interrupt (/WDTINT) is generated which stops abnormal program execution. If the microprocessor can still respond to the interrupt, a "fatal" software routine will execute, displaying an error code HLP - 4.

3. The interrupt signal /WDTINT, is used to generate /WDTFL, which disables the Base Voltage Generator and Waveform Generator, preventing further generation of RF output.

4. The MACHINE lamp on the front display is illuminated by WDTFL which is also derived from the interrupt, /WDTINT.

The Watchdog Timer (WDT) is made up of a dual, retriggerable, one-shot multivibrator (U7), associated RC timing components (R4, C5, R6, and C6), the relay power enable register (U10), and associated gates (U5 and U6). A WDTSTB is generated whenever U10-2 and U10-3 are both low. The first stage one-shot is set to time out at the minimum WDTSTB interval of 10 msec by the RC combination of R4 and C5. The trailing (falling) edge of WDTSTB triggers the first stage causing Q1 (U7-6) to go true (high) for approximately 10 msec. The rising edge of Q1 triggers the second stage one-shot via U7-12, causing Q2 (U7-10) to go high and /Q2 (U7-9) to go low. The 15 msec timing of this stage is set by the RC

combination of R6 and C6. In normal operation WDT strobes will occur after stage 1 has timed out (Q1=0) but before stage 2 times out (Q2=1). The one-shot is retriggerable and the rising edge of Q1 will restart the 15 msec timing sequence in the second stage even though it may not have completed its current time delay. Normal operation is indicated by /WDTINT (Q2) never going low.

The relay enable flag, RLYEN-Q from U10-10, is reset on power-up. This permits the microprocessor (U3) to test the WDT during initialization without allowing RF to appear at the outputs. While RYLEN-Q is disabled (low), the WDT will not lock up, permitting the software to test for correct operation. This is done by strobing the WDT early (less than 10 msec), late (greater than 15 msec) and looking for the generation of the interrupt /WDTINT (Q2=0). The WDT is then triggered within the correct time window (10 to 15 msec) and should result in /WDTINT remaining high. If these results are obtained, the WDT timer circuitry is operating normally.

After initialization is complete, the microprocessor generates a WDTSTB at the start of the first normal program timing cycle. The relay enable flag, RLYEN-Q, is set by the NOR gate, U10-5 and U10-6 both going low. After this, the program enters the normal operation program loop.

If a WDTSTB is not generated within 15 msec of the previous strobe, the second stage will time out and Q2 will go low resulting in a /WDTINT. Since RYLEN-Q and /Q2 (U7-9) are high, the inputs to U6-4 and U6-5 are both true resulting in its output (U6-6) going low. This resets the first stage one shot. Now that Q1 (U7-6) cannot go high, Q2 (U7-12) is prevented from being retriggered. With the WDT Q2 output gone low, the microprocessor will execute a WDT failure interrupt routine in response to /WDTINT falling, WDTFL will turn on the MACHINE FAULT Lamp and /WDTFL will disable drive to the power amplifier.

If the WDTSTB is generated before 10 msec, while Q1 is high, the NAND gate (U6-1 and U6-2) will both be high resulting in U6-3 going low and resetting the second stage. This causes the same results as the late strobe described above.

Note that the signal which causes the WDT to latch and ignore all subsequent WDTSTB pulses is RYLEN-Q being high. The only way to reset RYLEN-Q is a Power On Reset.

3.4.2 Power On Reset

The Power On Reset (POR) circuit consists of a single chip specifically designed for this function, A3U4, and associated components R1, U5, and Q3. The POR circuit monitors +5 Vdc (U4-8) and the output signals RST (pin 5) and /RST (pin 6) become active if +5 Vdc fails below 4.75 Vdc. The 8031 microprocessor operation is specified down to 4.5 Vdc. This allows power supply margin for proper power down of the controller until reset occurs. When /RST is low, the microprocessor is reset via the Inverter U5-12. At the same time, the signal, RST, goes high which is inverted by Q3 forcing a /RD. This prevents inadvertent writes to the NOVRAM during power transitions, when the control and address/data busses are in unknown conditions. On power up, RST and /RST are kept active for a minimum of 250 msec to allow the power supply and microprocessor to stabilize.

The power monitor (U4), also provides an input (pin 1) for direct connection to a switch (A3S1-4). Any time /PB is low for over 10 msec, the outputs RST and /RST become active. They remain active for a minimum of 250 msec after the switch is moved from the "/RST" position.

One last feature of this circuit is its function as a secondary watchdog timer. This is enabled by the connection of Address Latch Enable (ALE) from the microprocessor (U3-30) to U4-7. The RST and /RST outputs are forced to an active state when the /ST input (U4-7) is not stimulated for 1.2 seconds. This function is not normally used because it requires a failure in the microprocessor and the Watchdog Timer circuitry. This is considered a double fault condition and the odds of the two occurring simultaneously is very low. Also, it is possible for ALE to continue in normal operation while other parts of the microprocessor are not. The WDT circuit described previously is used because it is not susceptible to this failure in fault detection.

3.4.3 Digital I/O

The four digital ports of the 8031 (U3) are functionally assigned as follows:

PORT 0 (P0.0 - P0.7). This port serves two digital functions: 8-bit data bus for communicating with external I/O, and low-order address bus for accessing external Program Memory.

PORT 1 (P1.0 - P1.7). This port is dedicated to discrete inputs or outputs. Port 1.1 reads the position of the default settings jumper, JMP1. Port 1.2 generates the signal /RFEN used to control RF output. Port 1.3 is /LOUD which bypasses the audio volume control during alarm conditions. Port 1.4 reads the signal ARMCOMP which is supplied from the comparator U23-13. ARMCOMP is used during a software controlled successive approximation routine to determine contact resistance of the Return Electrode. Port 1.6 /NVEN (Non-volatile Enable), is a special flag, which along with /CAL generated by A3S1, allows the microprocessor to write to the Non-volatile section of the NOVRAM (U2) during the calibration routine. Port 1.7 handles serial data and port P1.0 generates serial clock (SCLK) for the last setting EEPROM (A2U4).

PORT 2 (P2.0 - P2.7). This port supplies the high-order address bus which reads from external Program Memory and writes to external I/O. All I/O is memory mapped so that distinct addresses access specific devices. The system is configured so that only one device is addressed at a time.

PORT 3 (P3.0 - P3.7). This port generates special signals used to control the overall system. These are /RD, /WR for reading or writing to external I/O, /PSEN (Program Store Enable) which enables the external Program Memory to the bus during instruction fetches, and ALE (Address Latch Enable) used for latching the low-order byte of address during access to external Program Memory. Port 3.1 generates the signal, /TONE, which is the source of the various audio tones used to signal activation or alarm conditions. Port 3.2 is the input for external interrupt, /WDTINT, from the Watchdog Timer. Port 3.3 is the input for the external interrupt, /IFAIL, generated by the current monitor.

The Address Decoder (U9), is used to select external I/O devices for reading and writing. High-order address to the decoder inputs (A10, A11, and A12) cause the corresponding output (Y0 -Y7) to go low. After address decode has stabilized, either /RD or /WR will go low to execute a data transfer with the addressed device.

Peripheral Interface Adapter (PIA), U11, is a general purpose I/O device designed to expand the number of addressable I/O lines available. It has three additional 8-bit ports (PA - PC) or 24 individually programmable pins. Port A is configured to read switch closures from hand and foot controls; Port B supplies an address to the Waveform Generator used to select specific output waveforms depending on the mode and power selections. Port C is used to activate the required relays to direct RF output to the appropriate accessory, and to enable the RF power supply.

3.4.4 Memories

The program used by the microprocessor is stored in external memory, the 32 K byte EPROM (U1). It is programmed and verified at the factory to ensure correct operation of the ESU. The memory is divided into 4 K byte pages. The odd pages are used for run time code which is accessed during normal operation of the electrosurgical unit. The even pages can only be accessed when switch, A3S1, is in the CAL position. This gates the address line A12 through OR gate (U8-3) to the EPROM. When A3S1 is in RUN, A12 is forced high.

Register U24 captures the low order address byte (AD0 -AD7) when ALE goes True. The data is then enabled on to the same bus when /PSEN and ALE are both low (0,0). In this manner the address/data bus (AD0 - AD7), alternates between carrying the low order address for the next instruction from the microprocessor and reading the data, which is the code for the next program step, back to the microprocessor. The high order address bus (A8 - A12), is used for addresses only and does not require latching since the information is available during the entire memory read operation. The only time /PSEN is active is during a program instruction fetch. When the microprocessor is addressing external

I/O, such as the PIA or NOVRAM, /PSEN remains high. AD0 - AD7 is an I/O bus whenever /PSEN is high.

The Nonvolatile Random Access Memory (NOVRAM), U2, is a 128 x 8 bit high speed static RAM overlaid bit-for-bit with a non-volatile electrically erasable PROM. This device stores the calibration coefficients used by the microprocessor to control accurate power output levels and to measure return electrode resistance. These values are stored in the non-volatile portion of the NOVRAM during the calibration procedure. In order to change these numbers, switch A3S1 must be in the CAL position to allow the signals /NVEN (Nonvolatile Enable) and /WR through the OR gate (U8-8 and U8-11). During normal operation, a write to the NOVRAM is not allowed.

When the ESU is powered up, the data stored in the non-volatile section of U2 is automatically copied onto the static RAM where it is accessed by the microprocessor via the address/data bus.

Each time the ESU is activated, the current set of power, mode and pad selection settings are saved in A2U4, an Electrically Erasable PROM (EEPROM) which retains data without power. The microcontroller communicates with A2U4 over a bidirectional, synchronous two-wire bus, SDAT and SCLK. Write access requires a special 16 bit preamble, which provides good protection against accidental alteration of stored data during power transients. The contents are further protected by a stored 16 bit CRC code. If the microcontroller detects a CRC error during a power-up read, the settings will default to zero power, pure, monopolar and dual.

3.4.5 Base Voltage Generator

The base voltage generator is schematically depicted on the A3 Controller Board Schematic, Figure 5.6b. It is microprocessor-controlled with two analog feedback paths that can turn the base voltage down in case of excessive power amplifier current and high output voltage. The high voltage shutback is not active in monopolar coag modes.

The base voltage generator is made up of an 8 bit DAC (U20), a differential amplifier (1/4 of U21), an inverting breakpoint summing amplifier (1/4 of U21), and power transistor A8Q1. U20 provides the input voltage selected by the microprocessor on the bus AD0 - AD7. R25 is a passive pull down required by the DAC to reach the lower DAC output voltages. Since resistor R32 includes the power transistor A8Q1 in the opamp feedback loop, the combination of Q1 and U21 (pins 1,2, and 3) may be considered as a power opamp for analysis purposes.

The -ISENSE and IGND signals are developed in the RF power amplifier on the Power Conversion Board A4. These signals are generated by the power amplifier supply current passing through sense resistors A4R4 and R5. The resulting voltage is proportional to the total dc current used by the RF power amplifier. The portion of U21 that includes pin 5, 6, and 7 makes up a low pass filtered differential voltage amplifier that amplifies the -ISENSE voltage by 10. The resulting ISENSE voltage is proportional 0.5 V/A to the dc current drawn by RF power amplifier from the RF supply. When ISENSE exceeds the voltage at U21-3 by a diode voltage drop, the ISENSE feedback loop becomes dominant and backs VBASE down to maintain the RF power amplifier current at its limit. This is independent of microprocessor control and is an additional safety feature.

During monopolar coag mode, either WV6, WV7, or both will be high, thus forcing pin U8-6 high, which in turn makes U12-12 go low. This action prevents the VSENSE voltage from turning back VBASE to limit RF output voltage. In all other modes, U12-12 floats and allows VSENSE to be active. When VSENSE exceeds the voltage at U21-3 by a diode voltage drop, the VSENSE feedback loop becomes dominant and turns VBASE down to limit the amount of RF output voltage. This action occurs primarily at high power settings of monopolar cut at high load impedances to prevent unwanted arcing at the active electrode.

The inverting breakpoint amplifier (pins 1,2, and 3 of U21) gain varies with the VDAC input voltage. Refer to Figure 3.6. When VDAC is in the high range (producing a low VBASE since the amplifier inverts), the incremental gain is -R32/R26. This low gain provides a finer control

of VBASE at the low power settings. At lower VDAC voltages, diode D5 becomes forward biased so that R9 is essentially in parallel with R26. Then the incremental gain is (R32/R26+R32/R9). This steeper gain allows VBASE to reach the voltage levels necessary for the higher power settings. The voltage where the gain slope changes is determined by the Thevenin equivalent of +12V, R11, R10 (shown as Vth and Rth in Figure 3.7) and R9.

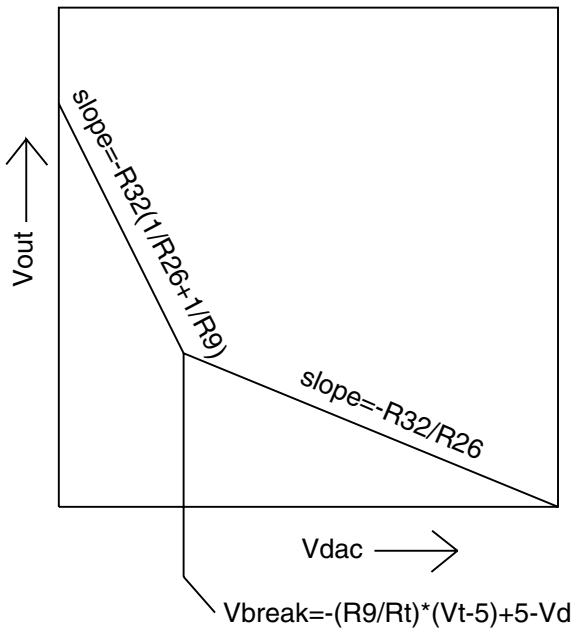


Figure 3.6 Base Voltage Generator Transfer Curve

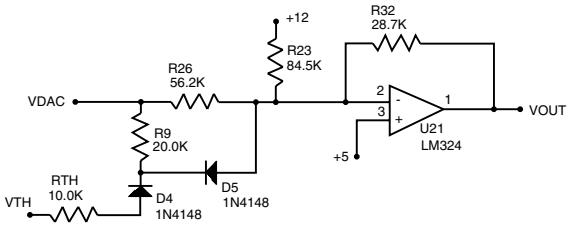


Figure 3.7 Basic Inverting Break Point Amplifier

R34 and R35 form a voltage divider to generate a 5V offset for U21-3 to allow single supply operation and to give a reference point for the VSENSE and ISENSE voltages. When RFEN is low U23-2 forces that voltage divider low, which causes VBASE to turn off. A similar action occurs when /WDTF goes low. R23 is summed into the breakpoint amplifier to subtract out the effects of the 5V on the non-inverting pin of the amplifier, thus allowing the output of the base voltage generator to go to zero.

3.4.6 IFAIL and A.R.M. Analog Input

Refer to Figure 5.6b for the schematic containing the IFAIL DAC A3U19. The output of this 8-bit DAC (2.55 Vdc maximum output voltage) is fed into the reference input of U23-9. The DAC is controlled by the microprocessor to produce a reference voltage for each mode of operation and power setting. The ISENSE signal (refer to Section 3.4.5 for a description of ISENSE) is voltage divided and lowpass filtered by R39, R49, and C61. Whenever the resulting voltage exceeds the reference input voltage provided by the DAC U19, a /IFAIL alarm is generated, warning the microprocessor that the RF power amplifier current is exceeding the maximum allowed for that particular output mode and power setting. This is a fatal alarm that produces a "HLP - 5" code and shuts down the ESU. Although it is possible for this to occur because of a temporary fault condition and may be recoverable by cycling power, it generally occurs because of a component failure in the Power Amp circuitry.

Note that the same DAC is used for the A.R.M. circuitry approximately every 12 milliseconds for about 200 microseconds. During that time, the microprocessor ignores /IFAIL since the reference voltage provided by the DAC is being used to provide a signal for the ARMCOMP comparator. See Section 3.2.2 for a more detailed explanation of the A.R.M. circuitry.

3.4.7 Waveform Generator

Refer to Figure 5.6b. A3U18 is a 32K x 8 EPROM that stores the bit patterns for the waveforms that drive the RF power amplifier. The EPROM is arranged so that the upper address

lines, WV0-WV7, determine which waveform is selected by the microprocessor, and the lower address lines, A0-A6, determine which byte of the waveform is selected at a time. The lower address counter (A3U15 and A3U16) cycles through its count to sequentially select each byte of the waveform and to reload its own count modulus at the beginning of each waveform. The selected byte of the waveform is then parallel-loaded into shift register A3U17, where it is serially-shifted out to the buffers U13A and U13B one bit every 50 nanoseconds.

A3U14 is configured as a modulus 8 counter that controls the parallel loading of the shift register A3U17 and increments the lower waveform address counter (A3U15 and A3U16). Both the loading and incrementing occur on the rising edge of the 20 MHz clock when /SRLOAD (U14-11) goes low and then high. A3U14 also generates 2.5 MHz and 10 MHz clocks from the 20 MHz oscillator Y1 for clocking the Display/Keyboard Driver/Encoder A2U2 and the microprocessor A3U3.

Each time /SRLOAD goes low and then high, the lower waveform address counter formed by A3U15 and A3U16 advances its count. The outputs from this counter (A0-A7) select the next 8-bit word to be loaded into A3U17 from A3U18. When the lower waveform address counter reaches it full count, i.e., the entire waveform has been completely outputted, /CNTRLD goes low on the next count and the address counter is preloaded to the pattern presented to it by O0-O7 of A3U18. This pattern sets the modulus of the address counter and thus the length of the waveform bit pattern. /CTRLOAD also clears the shift register A3U17 to zeros to prevent putting the modulus pattern out to the power amplifier. Since /CTRLOAD is low only at the beginning of a waveform, it is an excellent point to use for a scope trigger when examining waveforms (use TP20).

U13 provides both buffer and enable functions for the waveform generator. See Figure 3.5 for representative gate waveforms.

3.4.8 Tone Generator

Refer to Figure 5.6b. The operation of the Tone Generator is a voltage controlled current source that is switched on and off at the frequency of the desired tone. /TONE is generated by the microprocessor A3U3 at the desired audio frequency and is buffered by sections of A3U5 and A3U12 to generate the signal SPKR-. When SPKR- is inactive, no current flows through speaker A8SP1, thus there is no sound. When SPKR- is low, the current flow through the speaker is determined by R16 (which sets the minimum sound level per IEC 601-2-2 requirements) and the base voltage of A3Q2.

A9R1 (the volume control pot) and A3R18 form a voltage divider to set the base voltage of A3Q2. The emitter voltage of A3Q2 is one diode drop higher than its base voltage and is a constant for a given base voltage. This controlled emitter voltage across R15 means a current is flowing through A3Q2 that can be controlled by the base voltage. That is how the volume is set for normal operation. When an alarm is sounded, /LOUD from the microprocessor (which is buffered by sections of U5 and U12) forces the base voltage of A3Q2 into saturation regardless of the setting of the volume control pot. This is to assure that an alarm cannot be turned down in volume.

3.5 CONTROLLER FIRMWARE

The behavior of the Controller is a function of the custom program residing in the A3U1 EPROM memory. It must be replaced only with a factory programmed part. Most failures of this part may be traced to mishandling, particularly due to static discharge or to a secondary failure resulting from application of excessive voltage to the circuit, as may occur if a voltage regulator fails. However, since undetected EPROM failure could escalate a minor failure to a serious consequence in the O.R. environment, the program is equipped with many fail detection and shutdown features. Further, an independent external circuit (the Watchdog Timer) guards against a malfunctioning EPROM or 8031 operation. This safety system is discussed in the following overview of the firmware program.

3.5.1 RUN Mode

The following list of software functions begins at Power On Reset or by a manual reset performed by an internal CAL/RST/RUN switch.

The following initialization sequence must be successfully executed before the main working program can be entered.

1. Initialize outputs to relays and indicators.

2. Initialize all data memory locations for the working program.

3. Verify that the Watchdog Timer is functioning correctly and that it can control RF shutdown.

4. Verify that the RF current circuitry is operating.

5. Verify that no shorts exist in the hand/foot controls.

6. Verify that internal data memory input/output lines function properly and without crosstalk using a walking bit test.

7. Verify that the contents of program memory in all locations where the program resides is intact using a 16-bit cyclic redundancy check (CRC).

8. Verify that the contents of the calibration memory (NOVRAM) in all locations where data resides is intact using a 16-bit CRC.

9. Display 8s on all numeric LEDs and sound all four tones for operator verification, and illuminate all status indicators if all the previous tests have passed.

10. Copy the last setting EEPROM to mode and power registers if JMP1 is set to "last" and CRC is OK. If the CRC test fails, factory defaults will be loaded.

11. Enable RF output relays and pass control to the working program.

Failure of any of the above self-tests will result in the end of program executions, and a display of "HLP" on the Cut display. A 1 KHz tone is sounded to alert the operator and an error code is displayed on the Coag Power Level LEDs to indicate the Faults. See Appendix A.

The main program loop is executed continuously by calling the working subroutines and refreshing the Watchdog Timer circuit on each pass through the loop.

Hand control, foot switch, and return electrode inputs are monitored for changes. The validity of the input conditions are checked. The following conditions are considered illegal requests and result in a pulsing 1710 Hz operator error tone.

•Simultaneous monopolar and bipolar requests.

•Simultaneous Coag and Cut requests.

•More than two simultaneous requests.

•Any request other than Bipolar Coag with the Return Fault indicator ON.

In the case of an illegal hand/foot request, the last valid request is the one honored. Other operator actions that can result in a pulsing operator error tone are multiple or continuous pushbutton operation.

The current condition of the hand/foot controls and the keyboard are continuously monitored. When a valid request to change mode or power level is received, the displays are updated to reflect the change. When a valid request for RF activity is received, the following sequence is performed:

1. The appropriate RF indicator lamp and tone are activated.

2. The requested accessory output relay is closed.

3. The current limit fail-safe is set.

4. The power setting is used to retrieve waveform and amplitude parameters from the calibration memory which are then sent to the RF drive circuits.

5. RF output is enabled via /RFEN.

Self-tests are continuously performed during operation to ensure the integrity and reasonableness of hardware and software operation during the working program execution. Failure of these tests will result in a safe end-to-program execution (RF drive and all relays are disabled). A display of HLP on the Cut power levels LEDs and a 1 KHz tone alerts the operator to the condition. The MACHINE FAULT indicator lamp is illuminated, and the appropriate error code is displayed

on the Coag Power level LEDs to indicate the FAULT. See Appendix A.

3.5.2 CAL Mode

CAL Mode is used to gain access to and adjust the calibration parameters contained in the CAL NOVRAM, A3U2. CAL Mode also provides access to Watchdog Timer and Pseudo Run Mode diagnostics, which are provided to simplify troubleshooting of faults which would otherwise leave the unit inoperative due to fault detection during RUN Mode.

3.5.2.1 CAL NOVRAM Contents

Power calibration tables are stored in the NOVRAM for each mode of operation. During RUN Mode, each table is entered with the present power setting for the active mode, and the table returns a drive value to be passed to the VBASE Generator or Waveform Generator necessary to produce the set power. Table values are stored in 16-watt increments, and software performs linear interpolation to find drive values for intermediate power settings. During Power Calibration, each table value is adjusted up or down in steps of one when the power controls are moved while the unit is activated; the adjusted value is also driven out to the PA, causing output current to vary accordingly. The adjustment range for each entry is limited to +/-25% around a set of Program ROM nominals determined during product development.

When the unit is deactivated, the knobs are used to select table entries, which are associated with a "target current" display corresponding to the output power for that entry. Target current values are constants stored in Program ROM which have been calculated taking the selected load resistance option and characteristic load regulation into account.

Each table entry can be declared Calibrated or Uncalibrated. If the CAL NOVRAM CRC test passes on CAL Mode entry, all points are declared Calibrated; otherwise all are declared Uncalibrated. After entry to a Power Cal Mode, monopolar (CC) or Bipolar (bP), if any point is adjusted, then all other points which have not yet been selected and activated ("looked at") are declared Uncalibrated. Uncalibrated points are flagged by flashing target current displays. Restoring a point to Calibrated status requires only that it be looked at.

When Power Calibration is exited, software verifies that all points are Calibrated; if any remain Uncalibrated, a HLP 10 will be declared. Monotonicity (HLP 11) checks verify that successively higher-power entries in each mode contain successively higher PA drive values. If both of these checks pass, the NOVRAM CRC will be recalculated and stored. Otherwise, the CRC will be intentionally scrambled, preventing further operation (HLP 3) in RUN Mode. Cal Menu selections containing Uncalibrated or Non-monotonic entries will also flash.

The Cal NOVRAM also stores the VARM values for 10 and 150 ohm Return Circuit resistances provided during ARM Cal mode. The power cal load resistance options are also stored so that they need not be reselected each time.

3.5.2.2 CAL Mode Execution

Entry to and operation of CAL Mode is described in Section 4.3.

CAL Mode firmware is executed from power up or reset when A3S1 is set to CAL. If the PAD button on the control panel is not pressed at this time, the unit will terminate with a HLP 9 diagnostics code. This prevents a unit from being accidentally miscalibrated if put clinical service with A3S1 incorrectly set.

Initialization checks include program ROM CRC and RAM tests; as in RUN mode, if these fail, the unit will terminate with the appropriate HLP code (See Appendix A). Power amplifier tests are not performed so that Pseudo Run Diagnostics (dI 2) may be entered to aid troubleshooting faults which may cause this test to fail in RUN mode. If the WDT tests fail, the program branches directly to WDT Diagnostics (dI 1), since calibration is not possible with a faulty WDT circuit. The Cal NOVRAM CRC is tested; if that fails, a set of nominal calibration settings are loaded into the NOVRAM, and all cal points are declared Uncalibrated (flashing).

If all tests pass, the program will loop in Lamp Test mode with all LEDs turned on until PAD is pressed again. This permits a more thorough evaluation of lamp integrity than is possible during the brief RUN Mode test.

When PAD is pressed again, the CAL Menu will be displayed in the Coag Power window. Optional load resistance selections set during the previous CAL run will be restored from the NOVRAM and displayed in the Cut Power window. The Menu selections are displayed in rotating fashion when the Coag Power control is rotated, and the Options are similarly selected when the Cut Power Control is rotated.

When the desired Menu and Option are selected, they are entered when the PAD button is pressed. In Monopolar Cal (C-C), the power controls select the desired cal point while the unit is not being activated, and make single-step increments or decrements in the PA drive and the selected NOVRAM cal value when the unit is activated. Upon deactivation, the last cal value remains in the NOVRAM location selected. Adjustments are limited to +/-25% around the nominal stored in Program ROM to prevent "calibrating around a failure."

If a single point in a Cal Menu selection is adjusted, then all other points in that selection are flagged as uncalibrated. Those points are returned to calibrated status when they are selected and the unit is activated, whether or not they are adjusted.

Exit from a Menu selection is achieved by pressing PAD again. Before returning to the Cal Menu display, the firmware performs quality tests on the stored cal point values. If a value is out of expected range, left uncalibrated or non-monotonic, a HLP Code is displayed, but the program is not terminated. Upon the next PAD press, the CAL Menu is displayed, with the problematic Menu selection now flashing. If the tests pass, the CAL Menu will be returned to without a HLP code, and the selection will not flash.

Diagnostic Modes do not return to the CAL Menu. Once entered, exit is gained only via RST or cycling power. Once a CAL Menu selection which produces output power is entered, the WDT Diagnostics (dI 2) Menu selection is no longer available, since RLYENA has been set to provide output, but also forcing the WDT to lock up permanently if WDT-Q2 ever fails.

Pseudo Run Diagnostics (dI 1) is simply RUN Mode with all fault detection processes bypassed. It is useful for troubleshooting faults which will otherwise disable the machine. It will also allow the unit to be operated with all PA fuses removed; this condition will result in HLP 5 in RUN Mode.

3.6 USER INTERFACE

The Display PWB Assembly (A2), in conjunction with the Control Panel (A1), is the user interface to the unit for all inputs except hand and foot controlled activation requests. Power settings, mode requests, and return electrode alarm set point are all entered via the front panel membrane switches. The various indicators and displays supply machine operating status. These include requested power, mode, return electrode resistance, and alarms if they occur.

3.6.1 Displays

Refer to the Display Schematic Figure 5.5.

The MACHINE FAULT indicator is controlled separately from the rest of the displays. It is hardwired to the WDT circuit and in the event of a Watchdog Timer interrupt, this LED is illuminated when the signal WDTFL from J1-4 is high, causing Q1 to turn on. Since this indicator is hardware controlled, it illuminates in the event of a machine failure even if the microprocessor cannot process the Watch Dog Timer Interrupt.

The control of all other displays, power controls and the control panel pushbuttons is performed by the Keyboard/Display Interface, U1. Multiplexing of the displays is implemented by the outputs SL0 - SL2 counting in a binary fashion which is decoded by U2. The outputs of the decoder (U9), go low sequentially (/S0, /S1, /S2, /S3, etc.) scanning each digit, discrete LED group and bar group. The internal circuitry of U1 reads each digit data stored in internal RAM and drives the segment output (B0 - B7) in sync with the scan lines. Current is then supplied to the cor-

rect digit, displaying the appropriate number. The segment outputs of U1 are connected to the current driver U3 and RN2 which delivers approximately 40 mA to each segment. The displays are common cathode variety so that the current is supplied to the anode and pulled to ground at the common cathode connection by the scanned open collector driver U2. This current level is required to ensure sufficient brightness at 1:8 multiplexing. The SiC blue LEDs, D9-11, require over 100 mA peak multiplexed current to achieve useful brightness. Transistors Q2-4 are driven by U2 to boost its sink current for these devices.

3.6.2 Controls

Control pushbuttons are part of the A1 control panel and are connected to the Display PWB through connector J3. There is also a ground connection from the front panel electrostatic shield which is incorporated into the membrane switches. This ground strap is connected directly to the chassis and prevents electromagnetic interference and electrostatic discharge from being conducted into the logic circuitry via the membrane traces. Each pushbutton is normally open and is common to circuit ground at J3-1.

Output power adjustment is done via 36 step/revolution rotary encoders, ENC1 and ENC2. When rotated from one step to the next, only one of the two encoder contacts will close or open. The microcontroller reads the state of each encoder signal A2U1 RL0-3 every 4 ms. The firmware detects each step change and its direction for further processing.

3.7 POWER SUPPLIES

Refer to Figure 5.4 for a schematic detailing the chassis-mounted power supply components.

The Sabre 180 is designed to operate from 100, 115 or 230 volt, 50-60 Hz, single phase AC mains power. The detachable power cord is connected via a standard CEE-22 6A inlet on the rear panel. A safety ground in the power cord bonds the chassis and circuit common to earth. This cord should always be connected to a properly grounded AC receptacle to insure that an internal mains-to-chassis short does not create a serious shock hazard to the user.

Mains overcurrent protection is provided by a pair of 5 x 20 mm 250V externally replaceable slow-blow fuses, also on the rear panel.

CAUTION: Fuses should be replaced only with the type and rating marked for the strapped voltage range.

3.7.1 Mains Isolation Transformer

Transformer A6T1 steps the mains voltage down to separate 40 VAC and 22 V CT AC secondaries. The 40 V secondary is full-wave rectified to supply bulk unfiltered dc to the RF amplifier switching power supply. The other secondary is rectified and filtered to provide the +28U and +14U unregulated low voltage sources.

The dual primary is tapped and dressed out to a 6-pole screw terminal block, A6TB1, which provides easy access for strapping the mains for any of the specified nominal mains voltages. The same transformer is used for all mains voltages, but mains fuse ratings are different for the series and parallel primary strap configurations. See Section 4.4.1 for strapping changes.

Leads 3 and 6 contain internal thermal fuses to guard against insulation failure in the event of a mild overload which does not open the mains fuses. If either of these devices operates, the power transformer must be replaced.

3.7.2 Low Voltage Supplies

Refer to Figure 5.7a for schematic details of the Low Voltage Supplies.

Rectifier A6BR2 acts as a full wave bridge to source the +28U supply which is filtered by electrolytic capacitor A4C11. The voltage on this supply varies with mains voltage and RF output power, but is typically around +28 VDC at nominal mains and idle.

+28U is delivered to the A3 Controller PWB (See Fig 5.6) via A6W6 to supply the VBASE pass transistor A8Q1, the +12V regulator A3VR1, the Tone Generator and the Relay Enable switch A3Q1. Note that the +28U supply is denoted as +16V in Fig. 5.7; this reflects the approximate value of this supply in another application.

Similarly, the output of A3Q1 is denoted +28RLY; this source is regulated to +15V dc (VRLY) by A4VR3 for use by the output selection relays. The +28U supply is also used on the A4 Power PWB as a bulk source for the +12V regulator VR1, which supplies the gate driver U3 and the Isolated Power supply U2, Q10.

Half of bridge A6BR2 also serves as a center-tapped full wave rectifier to source the +14U supply, which is filtered by A4C15. The +14U supply is delivered via A6W6 to the A3 PWB, for the +5V regulator A8VR1, and to the A2 Display PWB to source all of the LEDs. This supply is also used on the A4 PWB by the +5V regulator VR2, which supplies regulated +5Vdc to the A2 PWB via A6W6.

3.7.3 RF Power Supply

Refer to Figure 5.7a for schematic details. This circuitry comprises a 100 KHz boost mode switching regulator to generate regulated +72V dc (RFSUP) for use by the RF Power Amplifier. When the unit is not activated, this supply is shut down, and RFSUP drops to about 50V dc unregulated.

Power FET Q1, inductor L1, rectifier CR1, and capacitors C1 and C2 serve as the 100 KHz power switching components which boost the unfiltered, rectified 40 V input to +72V dc. When Q1 is turned off, as during deactivation, RFSUP becomes an unregulated +50V dc source, passing through CR1 and filtered by C2. Unlike offline switching power supplies, this circuitry is isolated from the mains by A6T1 and thus can be worked upon without use of an external isolation transformer.

RFSUP feeds Q3, which by use of 18V zener D1, provides regulated +17V dc to the RF Supply controller, U1. Overvoltage protection is provided by Q4, which will kill the +17 supply if RFSUP ever rises above about +95 V. LED CR2 serves as a rough indicator of the voltage on RFSUP, and glows noticeably brighter during activation when Q1 is switching and RFSUP is up to +72V. It also serves to indicate when C2 has bled off below about 20V after the mains switch is turned off.

IC U1 is a special type of switchmode control IC known as a Power Factor Controller (PFC). This device operates to force the low frequency current draw from the 40V source to retain the same sinusoidal waveshape as the +40U input source voltage. Switching and regulation continues over the entire mains frequency cycle, so the current drawn from the 40V secondary of A6T1 appears the same as if were supplying a simple resistance.

Thus the AC input power factor is unity, and the AC power drain is equal to the DC output power drawn from RFSUP, plus a few watts of switching loss. Ordinary capacitively filtered DC supplies draw 180% or more AC volt-amps from their source as a function of DC power output. The PFC control used by this ESU requires a much smaller and lighter power transformer than would otherwise be required, while retaining excellent mains isolation, conducted noise suppression, surge tolerance and power factor.

U1 operates much like an ordinary current mode device in that it turns Q1 on at the beginning of every 100 KHz clock cycle and turns it off when the instantaneous current through L1 and Q1 rises to a predetermined level. That current is measured as the negative voltage VRS across the 0.05 ohm equivalent resistance of R1 and R2.

The turnoff threshold for VRS is determined on each switching cycle by the DC output voltage RFSUP, the RMS value of the AC input voltage and the instantaneous value of the AC input voltage. A sample of RFSUP is divided down by R8 and R9 to +7.5V at pin 11 VSN. An internal error amplifier adds in loop compensation via feedback network R10, C18 from its output at pin 7, VAO. The RMS value of +40U, monitored on pin 8 VRMS, is found by lowpass filtering and dividing down by R15, 16 and C22. Finally, the low frequency value of the input current is monitored by pin 6 IAC via R17,18. The instantaneous turnoff value of VRS is derived as:

$VRS(off) = K \times [(7.5V - VSN) \times IAC] / VRMS^2$
where K is determined by other circuit constants.

RFSUP does contain mains-frequency ripple. This is because the power delivered by the switching section is a maximum at the peak of the AC input voltage, where its input current is also at its

maximum. The power delivered to the output at mains voltage zero-crossing is nearly zero. Mains frequency ripple on RFSUP is controlled strictly by C2, as in a conventional mains frequency supply. Capacitor C1 serves to absorb the 100 KHz peak energy, while C3 serves to minimize the magnitude of the 100 KHz current drawn directly from A6T1.

The PFCEN input on U1-11 is used to enable the switching regulator. It is biased ON via R12,13 and pulled low to the OFF state by the microcontroller via A3U22-14. The microcontroller enables PFCEN only during activation. The switcher may be shut down for troubleshooting by shorting PFCEN at TP14 to ground at TP13. C21 controls the "slow start" timing to cause RFSUP to rise with slight overshoot when PFCEN is enabled. R14 and C19 serve to set the operating frequency to about 100 KHz. R25,29 and C29,30 set the overall PFC loop gain and compensation. The PKL input on pin 2Y hard-limits the switching current to prevent damage to Q1. VREF on pin 9 is an internal stable reference source of +7.5Vdc used to set the DC output voltage on RFSUP.

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Maintenance

Section 4.0

4.1 GENERAL MAINTENANCE INFORMATION

This section contains information useful in the maintenance and repair of the Sabre 180. While the unit has been designed and manufactured to high industry standards, it is recommended that periodic inspection and performance testing be performed to ensure continual safe and effective operation.

Ease of maintenance was a primary consideration in the design of the Sabre 180. Maintenance features of this unit include microprocessor aided troubleshooting aids and calibration, built in fault detection, circuit simplicity, circuit protection, use of common parts, easy access to circuitry while the unit is operational, and fused power transistors. These features coupled with the warranty, loaner equipment, factory support, toll free phone service to the factory and available factory training ensure the user of a minimal maintenance effort and long service life.

4.2 PERIODIC TESTING

The Sabre 180 should be performance tested at least once a year. Every unit is supplied with a serialized Production Test Data Sheet that tabulates the results of the factory tests that were performed on the unit. This data is supplied so that it may be used as a reference for subsequent tests. Recommended periodic performance tests are listed in the following sections.

Instructions for cleaning and periodic physical inspection are contained in Sections 2.6.2 and 2.6.3 of this manual. Functional testing instructions for controls and displays appear in Section 2.3.1.

When comparing your RF output current readings to those on the Test Data Sheet, bear in mind that most RF ammeters may read an error up to 2% of full scale. This means an actual current of 0.60A may register on a 1A meter anywhere from 0.58 to 0.62A.

4.2.1 Ground Integrity

Equipment:

•Volt-Ohmmeter, Simpson 260 or equivalent.

Procedure: Connect the ohmmeter between the earth ground prong of the power plug and footswitch connector. Confirm less than 0.1 ohm resistance.

4.2.2 Mains Frequency Leakage

Equipment:

•Mains polarity reversing and ground interrupting AC power switch box.
•High Impedance AC Millivoltmeter (Fluke 8000 A or equivalent).
•Frequency Compensation Network (1K resistor in parallel with the series combination of a 10 ohm resistor and a 0.15 uf capacitor.
•Footswitch.
•Short hand switch jumper lead.

Procedure:

1. Connect the switch box to a non-isolated, grounded source of AC power at the unit's nameplate rating. Connect the ESU to the switch box, power up and set all power controls to zero.

2. Connect the compensation network across the meter AC voltage input terminals.

3. Set the meter to resolve 1 millivolt AC or less. With the compensation network connected, the meter may be read in microamperes (uA).

4. Connect the low side meter input lead to earth ground.

5. Connect the other lead to the ESU terminals listed below, one at a time.
•Either blue bipolar output jack.
•Either return electrode jack pin.
•Footswitch monopolar active jack.
•Red hand controlled active jack.

6. While monitoring the meter, check leakage current at each terminal in all eight combinations of mains normal/reverse, ground open/closed, unit deactivated/activated to the measured terminal.

Test limit: 10 uA.

NOTE: If the activated leakage current exceeds this limit, make certain that the power setting is zero for that output before continuing.

7. Connect the meter lead to foot switch connector terminal C. Cycle the switch box through all four ground and polarity combinations.

Repeat this test with the meter lead connected to the foot switch connector shell.

Test limit: 80 uA.

4.2.3 Aspen Return Monitor (A.R.M.) Calibration Check

Equipment:
Decade Resistance Box (DRB) with attached dual foil return electrode cable. The DRB must be adjustable from 0 to 160 ohms in 1 ohm steps and accurate to 1%. A dual foil return electrode cable can be made by cutting the cable and connector from a dual foil return electrode, and stripping the wires for connection to the DRB.

NOTE: Some DRBs may present a brief open circuit at the output terminals during switch movement. This may cause the A.R.M. software to calculate an erroneously high resistance reading. This effect may be minimized by making DRB setting changes quickly. If the resistance read during any of the following tests is above the upper limit, repeat the test carefully stopping in each 1 ohm step for at least 1 second.

Procedure:

1. Disconnect all accessories from the output panel.

2. Power up in the RUN Mode. Select Dual Foil Mode and confirm that Resistance Indicator has all ten green bars flashing and that the Return MONITOR Indicator is illuminated.

3. Using the test cable, connect the DRB to the Return Electrode Jack.

4. Adjust the DRB until eight bars of the Resistance Indicator are flashing. Confirm this occurs with the DRB set between 115 and 160 ohms.

5. Carefully advance the DRB in 1 ohm steps until all ten bars of the Resistance Indicator are flashing. Confirm that the DRB reads between 137 and 163 ohms.

6. Set the DRB to 7 ohms and confirm that the Resistance Indicator is dark and the Return Monitor is lit.

7. Select Single Foil Mode. Confirm the Return Monitor goes dark.

8. Increase the DRB in 1 ohm steps until an audible Return Fault Alarm is sounded and the Return Monitor Indicator is lit. Confirm the DRB is between 8 and 12 ohms.

9. Decrease the DRB setting in 1 ohm steps until the Return Monitor goes dark. Confirm that the DRB reads from 1 to 4 ohms less than the resistance read in Step 8.

10. Disconnect the DRB. This completes the A.R.M. calibration test. If any readings were only slightly out of range, first check the DRB with an accurate ohmmeter. If the DRB is accurate, recalibrate the A.R.M. limits in CAL Mode. See Section 4.3.3. If one or more readings were far from the mark, troubleshoot the A.R.M. circuitry before attempting recalibration. See Section 4.5.5.

4.2.4 RF Output Power

Equipment:
- Dual treadle foot switch.
- Bovie #12 adapter.
- Shorted return electrode adapter.
- Electrosurgical analyzer with 500 and 50 ohm loads.

NOTE: Analyzers with 300 or 400 ohm loads for monopolar and 100 or 125 ohm loads for bipolar may also be used with some loss of accuracy due to load regulation variations. See Section 1.3.

An RF output power instrument may be constructed using a 500 ohm, 100W and 50 ohm 50W non-inductive resistors and a set of RF ammeters ranging from 150 mA to 1.0 A full scale. Fast blow 250V fuses rated at the meter full scale current are recommended to prevent accidental meter failure.

Procedure:
1. Use test leads to connect an RF ammeter in series with the 100W resistor and one of the unit's return electrode jack and the foot switch controlled active jack.

2. Perform the monopolar power tests indicated in Table 4.1 depending on the value of the load resistor used.

3. Disconnect the RF ammeter and load resistor from the unit.

4. Use test leads to connect the RF ammeter in series with the 50W resistor and unit's blue Bipolar Accessory Jacks.

5. Perform the bipolar power tests indicated in Table 4.1 depending on the value of the load resistor used.

Note: The RF output power level checks of Table 4.1 correct for the load regulation characteristics of the Sabre 180. This results in output current levels that differ from the power setting when the $P=I^2*R$ calculation is done at other than the rated load. Refer to the Load Regulation Curves in Section 1.3 for details.

Mode & Load	Power Setting	Output Power (W)	Output Current (mA)	Power Setting	Output Power (W)	Output Current (mA)
Pure Cut						
500 ohms	100	90-110	424-469	35	30-40	245-283
400 ohms	100	89-109	472-522	35	29-39	269-312
300 ohms	100	88-108	542-600	35	25-35	289-342
Blend 1 Cut						
500 ohms	65	59-71	344-377	35	30-40	245-283
400 ohms	65	59-72	384-424	35	29-39	269-312
300 ohms	65	58-70	440-483	35	26-36	294-346
Blend 2 Cut						
500 ohms	50	45-55	300-332	25	20-30	200-245
400 ohms	50	45-55	335-371	25	20-30	224-274
300 ohms	50	45-55	387-428	25	18-28	245-305
Mono Coag						
500 ohms	80	72-88	379-420	40	35-45	265-300
400 ohms	80	72-88	424-469	40	35-45	296-335
300 ohms	80	71-87	486-539	40	34-44	337-383
Bipolar Coag						
50 ohms	50	45-55	949-1049	25	20-30	632-775
100 ohms	50	31-41	557-640	25	13-23	361-480
125 ohms	50	26-36	456-537	25	11-21	297-410

Table 4.1 RF Output Power Checks

4.2.5 RF Leakage

Equipment:
- 150 mA RF Ammeter with 1/8 A fuse.
- 200 ohm 10W Noninductive Resistor.
- Patient Plate Adapter Plug.
- Bovie #12 Adapter Plug
- 2 - Test leads, 1m max. length.
- Test lead, 10 cm max. length.
- Wooden table approximately 1m from floor.

NOTE: RF leakage is primarily the result of stray capacitance to earth from the activated terminal opposite the one being measured. If excessive leakage is observed, first ensure that no unnecessary connections, leads or hand capacitance are elevating stray capacitance. If an electrosurgical analyzer is used, ensure that it is connected only to the measured terminal and earth.

Procedure:
1. Ensure that the unit is fully assembled and all fasteners are tight.

2. Place the meter and resistors on the table so that they are at least 0.5m away from the unit under test and any other conductive surface.

3. Set the unit for full power in Monopolar Coag and Bipolar Coag. Connect the 200 ohm noninductive resistor in series with fused RF ammeter, and a common earth ground (the footswitch connector shell will suffice). One at a time, connect this series combination to each RF output terminal indicated in Table 4.2, and active the unit using the corresponding command. Confirm that no meter readings exceed the specified maximum. Hand control coag activation is accomplished by connecting a jumper between the center jack and the red jack of the hand controlled active connector.

>WARNING<
HAND CONTROL ACTIVATIONS SHOULD BE KEYED USING 3" OR LESS WELL INSULATED JUMPER(S). USE OF AN INSULATING ROD TO INSERT THE JUMPER IS ADVISED TO PREVENT RF BURNS.

MEASURED OUTPUT TERMINAL	ACTIVATION COMMAND	MAXIMUM LEAKAGE (mA)
RETURN ELECTRODE	MONOPOLAR FOOT COAG	97
RETURN ELECTRODE	HAND CONTROL COAG	97
FOOT ACTIVE	MONOPOLAR FOOT COAG	97
BIPOLAR LEFT	BIPOLAR FOOT COAG	50
BIPOLAR RIGHT	BIPOLAR FOOT COAG	50

Table 4.2 RF Leakage to Earth Tests

4.2.6 RF Leakage from Inactive Outputs

Equipment: Same as in Section 4.2.5

Procedure:

1. Set the unit for full power Monopolar Coag and Bipolar Coag. Connect the 200 ohm, noninductive resistor in series with the fused RF ammeter. One at a time, connect that series combination between the RETURN ELECTRODE Connector and each RF output terminal shown in Table 4.3, and activate the unit using the corresponding command. Confirm that no meter readings exceed the specified maximum. Hand control coag activation is accomplished by connecting a jumper between the center black jack and the red jack of the hand controlled active connector.

>WARNING<
HAND CONTROL ACTIVATIONS SHOULD BE KEYED USING 3" OR LESS WELL INSULATED JUMPER(S). USE OF AN INSULATING ROD TO INSERT THE JUMPER IS ADVISED TO PREVENT RF BURNS.

CAUTION: To avoid destroying the meter, never activate output terminal connected to the meter.

2. Disconnect the meter and resistor from the unit. Turn unit Power Switch OFF.

4.3 RECALIBRATION

Recalibration is necessary if the Power or ARM checks indicate that the unit fails to meet specifications. Make sure that the calibration problem is not due to a component failure first, however. Attempts to "calibrate around a failure" may result in failure of the Calibration Quality Tests and the need to operate the unit in Diagnostics Mode until the problem is corrected, followed by a complete recalibration. Common failures which cause low power output are usually found easily by checking for blown fuses in the Power Amplifier section, for instance. See Section 4.5 for further guidance on troubleshooting.

MEASURED OUTPUT TERMINAL	ACTIVATION COMMAND	MAXIMUM LEAKAGE (mA)
FOOT ACTIVE	HAND COAG	50
FOOT ACTIVE	BIPOLAR COAG	20
HAND ACTIVE	FOOT COAG	50
HAND ACTIVE	BIPOLAR	20
BIPOLAR TOP	FOOT COAG	20
BIPOLAR BOTTOM	FOOT COAG	20

Table 4.3 RF Leakage from Inactive Outputs Test

4.3.1 CAL Mode General

This unit may be completely calibrated without selecting or adjusting components. Parameters necessary to compensate for unit-to-unit manufacturing tolerances and to normalize performance to specification are stored digitally in a non-volatile memory device on the A3 Controller PWB. By use of external calibration standards and the unit's menu-driven CAL Mode, calibration may be completed quickly using only the normal controls and displays.

To enter CAL Mode:

1. Turn unit off. Open the top cover and set A3S1, accessible through a hole in the shield, to CAL Mode. Make sure shield is in place and close top cover.

2. Connect unit to an AC source of the nameplate rating. Connect a dual treadle foot switch.

3. Power up while pressing the PAD button. If a HLP 9 is displayed, the unit did not detect the PAD button closure. Power down, or cycle A3S1 to RESET and back to CAL, and try again.

4. Normal entry to CAL Mode is signalled by a continuous Lamp Test, with all display elements steadily lit.

5. Release and press PAD again. The "CC" menu selection will appear in the Coag window, and 300, 400 or 500 will appear in the Cut (Option) window. The Menu selections and options may be stepped through using the Cut and Coag Power Control knobs. See Fig 4.4 for available CAL Mode Menu and option selections.

The following sections contain only step-by-step calibration procedures. If difficulty is encountered, refer to the detailed description of CAL Mode theory and software in Section 3.5.2.

Upon completion of calibration, ensure that the shield is securely installed, switch A3S1 is in RUN Mode, and the Top Cover is secured with both rear screws. Power up in RUN Mode to verify that a HLP 3 (NOVRAM CRC) fault is not declared before returning the unit to service.

MODE (COAG PWR)	MODE USE	OPTION (CUT PWR)	OPTION USE
CC	MONOPOLAR POWER CAL	300, 400, 500	SELECT LOAD RESISTANCE FOR MONOPOLAR CAL
bP	BIPOLAR PWR CAL	50, 100, 125	SELECT LOAD RESISTANCE FOR BIPOLAR CAL
Pd	ARM RESISTANCE CALIBRATION	BLANK	
dI	DIAGNOSTICS	1	WATCHDOG TIMER CHECK
		2	PSEUDO RUN MODE

Table 4.4 CAL Mode Menu

4.3.2 RF Output Power Calibration

Equipment:
•Electrosurgical Analyzer with 300, 400 or 500 ohm monopolar loads and 50, 100 or 125 ohm bipolar loads.

The most precise calibration will result when monopolar is calibrated at 500 ohms and bipolar is calibrated at 50 ohms. The analyzer should be set to read out in RF current.

NOTE: See Section 4.2.4 for instructions on assembling a suitable output power instrument if a suitable analyzer is unavailable.

•2 ea. 1m test leads.
•Bovie #12 test plug.
•Return Electrode shorting test plug.
•Dual-treadle footswitch.

CAUTION: To prevent damage to the analyzer, ensure that it is set to accept at least the selected target current before activating the unit. A unit in poor calibration may deliver well in excess of the target when first activated.

NOTE: To avoid thermal drift from producing inaccurate calibration, limit activation time to the minimum necessary to verify and adjust each point. If the unit appears to be getting excessively warm, or if power is consistently low toward the end of calibration, allow the unit to idle for a few minutes before continuing. This process may be expedited by directing a small fan or blower at the heatsink.

Procedure:
1. Connect analyzer to measure RF output CURRENT from the footswitched active and return electrode terminals. Set load at 500 ohms (preferred) or 300 or 400 ohms.

2. Enter CAL Mode per 4.3.1 above.

3. Select "CC" (Cut Coag) in the Coag window. Then set the analyzer load resistance in the Cut window.

4. Press PAD to enter Monopolar Cal mode with the selected resistance. The lowest Pure Cut and Monopolar Coag calibration target current values in RF Amperes will appear in the power windows. The leading decimal is assumed in the Coag window.

5. Use the footswitch to activate the unit in Cut mode.

6. If the output current does not equal the Cut target current, adjust the Cut Power knob until output current most closely matches the target.

7. Deactivate Cut and activate Coag.

8. Use the Coag Power Control knob to set output to target. If the target is "00", set the knob ONE STEP CCW from that which yields the lowest detectable output current (typically 20-80mA).

9. Deactivate the unit.

10. Select the next higher Cut and Coag targets by rotating the Power Control knobs one step CW while unit is DEACTIVATED. Lower targets may be selected using CCW steps if a target is missed. The highest target in any mode is selected when the target display no longer changes in response to CW steps.

11. While each new target current is displayed, activate and adjust output current, if necessary, for closest match. Remember to deactivate the unit to select the next target.

12. Use the Cut MODE button to select Cut BLEND 1. Using the above process, activate and calibrate all available BLEND 1 Cut targets. Repeat after selecting BLEND 2.

•If output current cannot be set to target, the unit may need service, or the analyzer load resistance does not match the selected option. Complete the calibration process without further adjustments (select and activate all targets in all modes). Correct the problem afterwards.

13. This completes Monopolar Calibration. Press the PAD button to return to the CAL Menu. A direct return to a steady "CC" Menu indicates that the Calibration Quality Tests were completed successfully.

•If HLP 10 (Incomplete Cal) appears, do NOT power down or move A3S1 yet. Press PAD. The CAL Menu selection which requires attention will be flashing. Reenter by pressing PAD. Search through all targets until those which are flashing appear. Activate and adjust if necessary. Repeat until no flashing targets appear.

•If HLP 11 (Non-monotonic) appears, the unit may require service, or the calibration procedure was improperly performed. Do NOT power down or touch A3S1 yet. Carefully review the procedure and proceed as with HLP 10 above.

If the unit is turned off or RESET with a HLP or any flashing menu selection, the unit will declare HLP 3 (NOVRAM CRC) when powered up in RUN Mode. A complete and correct monopolar, bipolar and ARM calibration must be completed to clear this condition in order to return the unit to service.

14. Connect the analyzer to the bipolar output jacks. Set analyzer to read output CURRENT to 50 (preferred) 100 or 125 ohms.

15. Select "bP" in the Coag window. Then set the analyzer load resistance in the Cut window.

16. Press PAD to enter Bipolar calibration.

17. There is only one target current in Bipolar. Activate the unit using the Coag footswitch. Check and adjust if necessary using the Cut Power Control knob.

18. Deactivate and press PAD. The "bP" CAL Menu selection should reappear.

19. This completes RF Output Power calibration. Before powering down or returning to RUN Mode, it's a good idea to step through all of the CAL Menu selections using the Coag Power Control knob. If any selection is flashing, re-enter that mode and complete checking any missed (flashing) targets.

20. If desired, the ARM Calibration mode (Section 4.3.3 below) may be entered at this time in lieu of returning to RUN Mode.

21. If any power calibration targets were adjusted, repeat the RF Output Power Checks, Section 4.2.4.

4.3.3 Aspen Return Monitor (A.R.M.) Calibration

This mode allows the unit to store the VARM values measured for 10 and 150 ohm return circuit resistances. See Section 3.2.2 for A.R.M theory.

Equipment:
•Return Electrode plug with unshorted leads.
•10 ohm and 150 ohm 1% 1/4W non-inductive resistors (metal film or carbon film checked for accuracy using an ohmmeter). Do NOT use wirewound resistors. An accurate Decade Resistance Box is also suitable.

Procedure:
1. Enter CAL Mode per procedure detailed in 4.3.1 above. The foot switch is not necessary for A.R.M calibration.

2. Using the Coag Power knob, select "Pd" (Pad) in the Coag window.

3. Press PAD to enter A.R.M Cal Mode. Entry is signalled by "10" (10 ohms) in the Cut window and a 2-bar resistance display.

4. Connect the 10-ohm resistor across the pins of the Return Electrode jack.

5. Pause a second to allow the measurement to stabilize, then press MONITOR SET. There should be no audible response, and the displays should not flash.

•The unit will respond with a beep and flashing display if it reads a VARM value outside the expected range. Make sure that the resistance value is 10 +/- 1 ohm and that it is making good contact with the Return Electrode jack pins. Repeat step 5. If the unit continues to refuse the setting, proceed with A.R.M Troubleshooting in Section 4.5.5.

6. Using the Cut knob, select "150" in the Cut window. An 8-bar resistance display will also appear.

7. Connect the 150-ohm resistor to the Return Electrode jack.

8. After a second, press MONITOR SET. If there is no beep or flash, A.R.M. calibration is complete.

If the unit refuses the 150-ohm calibration, it will also cancel the 10-ohm calibration. Make sure the proper resistances are well connected and repeat both 10 and 150 ohm calibrations.

9. Using the Coag knob, make sure that neither 10 or 150 ohm selection is flashing, then press PAD. Calibration was successful if the CAL Menu "Pd" appears steady.

•If HLP 10 appears after pressing PAD, press PAD twice to return to the ARM Cal mode and correct the problem before exiting CAL. Otherwise the unit will be declared uncalibrated and will declare HLP 3 when RUN mode is entered. Complete Power and A.R.M. recalibration will then be required before returning the unit to service.

10. This completes A.R.M calibration. At this point, monopolar or bipolar Power Calibration may be entered per Section 4.3.2 above. Otherwise, the unit may be returned to RUN mode using A3S1. It's a good idea to step through the CAL Menu selections using the Coag Power Control knob first to ensure that no selections are flashing.

11. After A.R.M calibration is completed and RUN mode reentered, repeat the A.R.M. Calibration Checks in Section 4.2.3.

4.4 OPTION SELECTION

The Sabre 180 may be reconfigured in the field to change the mains voltage range and to change the power-up setting restore feature. These selections may be made using ordinary hand tools. No soldering is required. Refer to Section 5.2 for internal access instructions.

4.4.1 Mains Voltage Strapping

The unit is factory-configured, fused and labeled for 100, 115 or 230V 50-60Hz AC operation. Field reconfiguration is simple, but the unit mains fuses must be replaced and the unit should be labeled to reflect the altered mains requirements. If the factory reconfigures mains voltages, the nameplate and fuse labels are replaced.

See Figure 5.4 for schematic representations of the three mains voltage strap options. All options are strapped using the A6TB1 terminals closest to the rear panel. TB1 pin numbers are identical to the numbers marked on A6T1 primary leads.

Equipment:
•Phillips screwdriver to remove top cover screws.
•1/8" (3mm) straight slot screwdriver or equivalent.
•Needle-nose pliers.
•Wire cutters and strippers.
•#18AWG 300V 80^{O}C white insulated stranded hookup wire.
•Replacement 5x20mm 250V slo-blo fuses for the new voltage range.
•Robust label stock to identify the new mains voltage and fuse rating.

Procedure:
1. Disconnect mains cord from unit.

2. Open top cover.

3. Locate A6TB1 above power transformer A6T1. Note that TB1 pins are numbered 1-6, left to right, corresponding to T1 lead numbers.

4. Refer to MAINS VOLTAGE STRAPPING in Figure 5.4. Notice that the black and white A6W1 leads connect to the rear half of TB1.

5. Loosen the rear TB1 screws as required to remove the connections not required for the new mains voltage range.

6. If restrapping from 230V to 115 or 100V, prepare a 2" (5cm) length of hookup wire, stripping the ends 3/16" (5mm).

7. Carefully twist wire ends and loosen TB1 screws liberally before inserting wires. This will prevent loose strands from pulling loose and causing ground faults. Needle nose pliers will be helpful. Paired wires should be twisted together before insertion.

8. While wires are inserted fully into TB1, tighten the corresponding screw securely. Verify security of the connection by pulling on the wires with the pliers. Be careful not to damage insulation.

9. After all wires are connected and checked for security, inspect your work carefully to ensure that no loose strands appear outside TB1 and that all connections are correct according to Figure 5.4.

10. Referring to Figure 5.4, replace mains fuses as required with the correct rating for the new mains voltage.

11. Prepare a label with the new mains voltage and fuse rating and attach securely to the outside of the rear panel near the mains inlet, A6J1.

12. Before closing the top cover, connect a shorting plug or single foil electrode to the Return Electrode connector and either a hand switch or foot switch to emit activation. Turn power switch OFF.

13. Connect the power cord to the unit and to a source AC power having the new voltage rating.

CAUTION: If either of the following checks fails, IMMEDIATELY turn the power switch OFF and recheck your work. Operation for more than a few seconds with incorrect mains strapping can cause permanent damage.

14. Turn power switch ON and verify normal power-up sequence. Select SINGLE mode. Verify RETURN lamp goes dark.

15. Observe A4CR1, the red LED near the rear of the A4 Power PWB. Verify that A4CR1 brightens noticeably when the unit is activated and gradually returns to original brightness after deactivation. Normal activation indications should operate.

16. If the above checks pass, close the top cover and secure it with the two rear panel screws.

17. The unit may now be returned to service. However, if equipment is available, the mains frequency leakage and RF output checks in Sections 4.2.2 and 4.2.4 should be conducted to gain added assurance that the unit is correctly restrapped.

4.4.2 Power-up Default Selection

The factory configures the unit to power up using the control panel setting stored in EEPROM during the previous activation. This feature may be overridden such that the unit always powers up with:
•All power settings zero.
•DUAL Mode.
•Pure Cut.
•Monopolar Coag.

This option is selected by a jumper JMP1 on the A3 Controller PWB.

Equipment:
•Phillips screwdriver.
•9/16" (14mm) nutdriver.
•Needle-nose pliers.

Procedure:
1. Turn power switch OFF.

2. Open Top Cover and remove shield cover per Section 5.2.

3. Locate 3-pin jumper JMP1 on the A3 Controller PWB. Notice that factory default position is labeled "LST" and the override position is labeled "0".

4. Carefully slide the 2-pin shorting jumper upwards and off the jumper pins and slide it back on in the new position. The center pin is common to both options.

5. With the Top cover still open, turn the power switch ON.

6. Select powers and modes different from those of the "0" option. Connect accessories as required to permit activation in any mode; footswitch activation in Bipolar Coag is the most straightforward.

7. Activate the unit once and note the settings.

8. Cycle the power switch. Verify that the unit powers up in the desired new configuration.

NOTE: If EEPROM A2U4 is defective, the unit will power up in the "0" condition regardless of the position of A3JMP1. Refer the unit to service, unless the "0" option is desired.

9. Turn power switch OFF.

10. Reinstall the shield cover, taking care not to crush any of the harness wires. Secure the shield using all four nuts.

11. Close the top cover, secure it with both rear panel screws and return the unit to service.

4.5 TROUBLESHOOTING

This section explains the troubleshooting aids built into the Sabre 180 and provides a guide to their use. Not all failures can be covered in a guide such as this, so the troubleshooter must by necessity understand the full operation of the unit. Read Section 3 for the description of system and circuit theory.

Section 5 contains schematics, part lists, PWB layouts and instructions for assembly removal and replacement.

>WARNING<
READ THE SAFETY SUMMARY IN SECTION 1.1.4 BEFORE TROUBLESHOOTING THE UNIT.

If trouble is suspected, perform a thorough visual inspection, looking for loose or burned components which may point to the source of the problem. Verify that all connections are clean and seated properly and that soldered harness connectors are sound and not shorting. Check all wiring for evidence of mechanical damage. Check the regulated and unregulated power supply voltages. Improper supply voltages can produce a multitude of problems. Check that the RF shield is in place and all mechanical connections are secure. Check all fuses. Check the operating instructions and see if the suspected problem was actually designed to work that way.

4.5.1 Using and Interpreting HLP Codes

The microprocessor is programmed with a number of fault detection routines designed to shut the unit down safely if a failure has occurred. This shutdown procedure will produce a HLP code that can help with the troubleshooting process. The following will further explain the HLP codes and other troubleshooting aids. Upon fault detection, the program will branch to an endless loop which displays a fault HLP code in the Cut and Coag power displays. This loop takes /RFEN false, forces VBASE and the waveform generator output to zero drive condition and commands the relays to open. Further, it ceases generation of Watchdog Timer strobes, causing illumination of the MACHINE lamp and redundantly disables base and gate drive to the Power Amplifier. If the Watchdog Timer detects a processor fault, it will issue an interrupt to the processor, causing a branch to the same routine as above if the processor is healthy enough to respond; if not, RF will still be disabled, but the only front panel indicator will be illumination of the MACHINE lamp.

Processor-controlled fault detection occurs extensively on power-up and to a lesser extent, continuously during operation. Each test is assigned a unique HLP number to be displayed on the Monopolar Coag Power Level Display.

Refer to Appendix A for a complete list of HLP codes and their possible causes. Appendix A is located at the end of this manual for easy retrieval.

4.5.2 Diagnostic Modes

Armed with a good understanding of the Theory of Operation in Section 3, one can make effective use of Diagnostic Modes in trouble-shooting faults which disable the unit during RUN Mode. Diagnostics are accessed in the "dI" Menu selections after entering CAL Mode, described in Section 4.3.1.

When the Diagnostics Menu selection "dI" appears in the Coag Power window, one may select Watchdog Timer Diagnostics as Option 1 (dI1) in the Cut Power window, or Pseudo RUN Mode as (dI2). Entry to the selected mode occurs when the PAD button is pressed. Exit is only via powering down or setting A3S1 to RST.

4.5.2.1 Watchdog Timer Diagnostics (dI1)

This section contains help in troubleshooting the Watchdog Timer on Controller PWB (A3).

A faulty Watchdog Timer (WDT) will cause the microprocessor to stop generating the WDTSTB signal in RUN mode. Troubleshooting this circuit is difficult without that signal, and setting up an external generator and connecting it to the circuit is time-consuming.

Diagnostics 1 mode solves that problem by using the microprocessor as an on-board programmable pulse generator. One may select one of three pulse frequencies by using the monopolar foot switch. One of the selections places pulses continuously inside the normal Watchdog Timer window, while the others are too early and too late. It is also possible to set RLYENA to verify operation of the lockup circuitry.

Since this mode is useful only with the RLYENA flag in the reset state, "dI" will not appear in the menu once RF has been activated in any of the power calibration modes. On the other hand, if a faulty WDT is detected on initial entry to CAL MODE, Diagnostics 1 will be automatically entered, bypassing the menu, since proper calibration may be impossible if the WDT is faulty.

An indication of the currently selected mode appears in the Bipolar Power window. Modes are selected round robin fashion by using the Coag (righthand) foot switch to step up to the next higher mode, and the Cut treadle to step down. Table 4.5 lists the available modes.

If the WDT is operating normally, the MACHINE Alarm Lamp will appear as shown above until Lockup Mode 4 is selected and then either Late Mode 2 or Early Mode 3 is selected. After that, the MACHINE Alarm Lamp should be bright in all modes. This indicates that the WDT has effectively locked up, as it should.

DISPLAY	MODE	WDTSTB PERIOD	RYLENA FLAG	MACHINE LAMP
1	Normal	12.0 mS	Unaffected	Dark
2	Late	18.0 mS	Unaffected	Dim
3	Early	8.0 mS	Unaffected	Bright
4	Lockup	12.0 mS	Set	Dark*

*on initial entry to Mode 4

Table 4.5 dI1 Modes

Since the WDT timing accuracy and ability to interrupt RF output are verified by the microprocessor on every power up, there is no need to recheck these parameters periodically. The only feature not checked automatically is lockout, which is extremely reliable due to its simplicity.

If the unit declares a HLP -4 error in RUN mode, then the timing is incorrect. Select Late Mode 2 to observe timing of both WDT one-shot stages at their test points. Stage 1 should go high for 9 to 11 mS after each WDTSTB, and Stage 2 should run from 13.5 to 16.5 mS. Slight timing errors are most likely due to a faulty timing resistor or capacitor. Failure of the pulses to respond at all are more indicative of an IC failure.

A HLP -7 indicates that the WDT did not shut down RF when Stage 2 timed out. This may be caused by failure of any of the components carrying the WDTFL signal to the WFG and VBASE circuits.

Most WDT faults can be diagnosed in Diagnostics 1 using a simple logic probe, but an oscilloscope will yield better timing measurements. The general health of the WDT can be confirmed with no instruments simply by observing the behavior of the MACHINE Alarm Lamp in the various modes.

4.5.2.2 Pseudo RUN Diagnostics (dI2)

In Diagnostics 2, the unit operates exactly as in normal RUN mode and will deliver RF to the output jacks, except software routines which detect hardware faults are not executed. The routine that checks for the Program EPROM CRC validity will still be active.

CAUTION: If any hardware failures exist, the microprocessor will not shut the system down or display a HLP code. One should be prudent in deciding whether or not to enter this mode without first attempting to identify the fault while powered down.

As an example of the above note, if there is a problem with the Power Amplifier which causes it to draw excessive current, say a shorted FET, then activating the unit can allow the fault current to flow for the duration of the activation. This may result in damage to other components which had previously been spared by the microprocessor's fast response to overcurrents in RUN mode. The time saved by not first performing an ohmmeter test of the FET will be lost in identifying and replacing parts damaged by the undetected overcurrent.

Diagnostics 2 allows the unit to be operated with the PA collector and base fuses removed, which is not possible in RUN mode due to the certainty of a HLP -5 shutdown during initialization.

4.5.3 Base Voltage Generator Troubleshooting

Remove all collector and base fuses on the A4 Power Conversion Assembly before checking a suspect Base Voltage Generator (BVG). Enter the dI 2 mode (see Section 4.5.2). Check that A3U20 is producing the proper VDAC voltage at TP14. Do this by selecting the Blend 2 Cut mode and increasing the power setting from 0 to 50W Monitor TP14 to see that VDAC goes from approximately 9.9 Vdc at 0W to 2.0 Vdc at 50W. The VDAC voltage at 50W will vary from unit to unit, the important factor is that the voltage changes in small increments.

Next monitor A3TP12 and repeat the above procedure. Confirm that TP12 voltage increases from no more than 0.5V at 0W to approximately 5.0V at 50W. If it fails to do so, check that VSENSE and ISENS are both less than 0.6V (this is true only if the PA fuses have been removed).

Other problem sources could be one of the resistor divider chains in the BVG, a bad RFEN or WDTFL signal. Also check that the other components in the BVG chain are correct and functional.

If the BVG performs correctly as tested so far, and the Power Amplifier and Waveform Generator both test good, proceed with the following test. Turn off the unit and replace the fuses in the PA. Reenter dI2 and select Blend2. Monitor A3TP13 (VSENSE) and slowly increase the power setting on the front panel. When functioning correctly, TP13 will increase with power setting up to about 5.0 Vdc. At that point, there should only be a slight increase in TP13 voltage. If TP13 fails to increase towards 5.0V, do not

proceed with this test; find the failed components and repair them.

After successful testing of the VSENSE circuit, connect a 500 ohm 100W load resistor to the unit's RF outputs. Select Pure Cut and slowly increase the power setting while monitoring TP15. The dc voltage at TP15 should increase as power increases, but should not exceed 5.0 volts at full power.

Units that have passed the troubleshooting steps so far should be checked for properly oriented diodes, mismarked resistors, and correct divider voltages. If the unit has passed these BVG checks, then the problem is likely elsewhere.

4.5.4 Waveform Generator Troubleshooting

Disconnect A4P3 before checking a suspect Waveform Generator (WFG). Enter the dI2 mode (see section 4.5.2). Check that a 2.5 Mhz clock appears at A3TP19. Select a power setting and mode that corresponds to the photos in Figure 3.5 and confirm the waveforms are similar to that at TP10 (use TP20 to trigger the oscilloscope to get comparable results). If they are not, suspect one of A3U13-U18 as being bad. Another problem could be in the waveform select lines WV0-WV7.

4.5.5 Aspen Return Monitor (A.R.M.) Troubleshooting

The overall functionality of the A.R.M. circuitry may be checked by selecting DUAL FOIL in Run Mode and connecting an accurate decade resistance box or selected resistors to either of the Return Electrode Jacks on the output panel. If the Resistance Indicator vs. resistance appears to match Table 3.1, then the circuitry may be assumed to be operating properly.

If this test passes, but the unit still declares unaccountable Return Fault in operation with the ESU activated, interference from electrosurgical current is the likely cause. Check the A4T5 shield lid for good electrical and mechanical contact with the shield cup, and capacitors A4C71 and C72 for proper value and connection. Also check bypass capacitors A4C59, A3C25 and low pass filter capacitor A3C38.

If the Resistance Indicator vs. resistance test fails, check BVARM at A3TP16 with 10 and 150 ohms connected to the Return Electrode Jacks. With 10 ohms connected, BVARM should be +0.88 to 0.98 Vdc and with 150 ohms, it should be +1.89 to 2.18 Vdc. BVARM should also match VARM at A3TP17 to within 10 mV dc. If this test passes, then the trouble is most likely in the DAC A3U19 or A.R.M. comparator circuitry around A3U23. Note that a faulty DAC is also likely to cause HLP-5 Alarms.

If the VARM vs. resistance test fails, check the dc current source by connecting a dc milliammeter from A3TP17 to ground. The meter should read from 0.49 to 0.51 mA.

If VARM test reads near zero and the dc current is low, repeat the current test with A3J2 disconnected to eliminate a possible VARM short to ground in the A6W4 harness or on the A4 PWB and shorted transistors A4Q5 or Q6.

With the Return Electrode Jacks open-circuited, check the waveforms on the A.R.M. oscillator collectors, A4Q5 and Q6. They should appear as (in Figure 3.2) frequency of 34.5 - 38.1 KHz. If the frequency is too high, A4C33, 34, 71 or 72 may be open. If the circuit is not oscillating and VARM is 0.6 - 0.8 Vdc, check the feedback resistors A4R19 and R20, transformer A4T4 for opens or shorts and transistors A4Q5 and Q6 for opens. If the circuit is oscillating at the correct frequency but VARM does not respond to resistance changes, check the circuitry from the secondary to A4T4 to the Return Electrode jacks for shorts or open circuits.

4.5.6 Power Amplifier Troubleshooting

The first step in troubleshooting a Power Amplifier (PA) is to remove all PA collector and base fuses (check the fuses as you remove them and note if any of them are blown). This will prevent possible secondary failures in the PA due to overload.

Use a VOM to check for shorted bipolar power transistors, power MOSFET, and snubbing networks. Check to see that diodes are functional. Check TP15 for approximately +50 Vdc and TP5 for +12 Vdc.

Check the Base Voltage Generator and Waveform Generator for proper function before proceeding. If everything checks this far, enter dI2 (see Section 4.5.2) and select Pure Cut from the front panel. Confirm that A4TP9 has approximately 0 to 10V signal swings, and the same shape as A3TP10.

Turn off the power to the unit and replace the base fuses. Reenter dI2 and select Pure Cut from the front panel. Use an oscilloscope on the drain of A4Q2 to confirm that the power MOSFET is switching properly.

If the unit has passed all tests to this point, it will be necessary to replace the collector fuses to troubleshoot further. Proceed with caution!

Observe instructions for heatsink mounted device replacement in Section 5.2.3.

4.5.7 Continuity Detector Troubleshooting

If the symptom is a HLP -8, stuck control switch, first ensure that the hand or foot switch was not accidentally closed by the user during power-up. Otherwise, isolate the problem by powering up with those accessories disconnected. If the symptoms persist, disconnect A4P5 and P6 to isolate the trouble to the A4 or A3 PWBs. The most likely culprit on the A3 PWB is A3U11. Otherwise, the trouble is in one of the four identical isolation circuits or one of the ribbon harnesses.

If the symptom is Failure to Activate, first verify that the hand or foot accessory is functional using a ohmmeter. Contact resistance must be below about 300 ohms to operate this unit. Troubleshooting the unit should begin by determining if all or only one the four isolation circuits is malfunctioning. This is easily determined while the unit is still in service by operating both hand and foot switch cut an coag switches and observing the unit's response. If the unit's response is normal, verify RF output.

If only one of the accessory lines exhibits trouble, and the others are OK, then the problem is likely to be isolated to its associated circuitry. Fault isolation may proceed most expediently by comparing voltages in the faulty circuit to those in an operational one.

The open circuit voltage on the switching lines should be about +2.7Vdc relative to the common switch line. If all four fail to cause the unit to respond, or the sense voltage is low, then the trouble is likely to be in the isolated power supply, A4U2 and Q10.

Use an oscilloscope to check Q10-D and U2-3 against Figure 3.3. If the waveforms and frequency appear correct, check for intermittents by moving the associated components with an insulated rod. If the Q10-D waveform deviates significantly from a half-sine, check for C43 open circuited or a shorted rectifier, D10 or D11, or shorted capacitor, C65 or C66. A broken ferrite core on T2 will also show this symptom. If the voltage on Q10-D is near zero, Q10 may be shorted, which will also pull the +12V supply down. If the frequency deviates significantly from 90 KHz, check the values of timing components R30, 31 and C22; if these appear OK, then replace U2.

If one of the handswitched optoisolators is replaced, its body should be covered in clear, self-bonding heatshrink to retain clearances required by IEC 601.

After repairs, verify that all switch inputs are functional, and that none of them respond with switch resistances over 1000 ohms. Verify that the FRET and H1RF lines remain isolated from ground.

4.5.8 RF Power Supply Troubleshooting

Turn power off first and remove all base fuses (F1-F3) and collector fuses (F4-F6). Then disconnect P2 and P6 from A4 to isolate the power supply circuitry from the system. Inspect mains fuses (A6 F1 & F2) to see if they are blown. Use a DMM to check the circuit connections and parts on the board, especially the power FET Q1, diode CR1, and capacitor C2. Replace bad components and fix open and short circuits if necessary.

Turn power on and measure the voltages at RFSUP (TP15, 68-76V), +17V (U1-15, 16-19V), +7.5VREF (U1-9, 7.2-7.8V), and PFCEN (TP14, 5.0-6.0V) with a DMM. With PFCEN shorted to GROUND, the RFSUP voltage should be read as follows:

MAINS INPUT	RFSUP Vdc
100V	50-54
120V	52-56
230V	50-54

Let PFCEN open and connect a 20 ohm, 250W power resistor from RFSUP to GROUND. The voltage at RFSUP should be in between 68-76V with no more than 6V peak-to-peak, 100Hz (50Hz AC line) or 120Hz (60Hz AC line) ripple.

Technical Data

Section 5.0

5.1 GENERAL

This section contains detailed information on all of the Sabre 180 circuitry. Foldout sheets allow schematic diagrams to be viewed while reading related text in Section 3 Theory of Operation and Section 4 Troubleshooting. Appearing with each schematic are printed wiring board (PWB) layouts, to aid in locating components, and lists of replaceable parts in reference designator order. Reference designators are numbered starting with "_1" in each assembly; they may be identified globally by adding an "A_" assembly prefix.

The HLP Code list, along with a description of the tests which produce them and possible causes, appears as Appendix A at the end of this Section.

5.2 ASSEMBLY STRUCTURE AND PARTS ACCESS

Referring to Figure 5.2, the Sabre 180 is divided into two major halves, the Base Assembly, A6, and the Top Cover Assembly, A8. When the Top Cover is opened, access is gained to the A4 Power PWB, A5 Output Panel and all A6 chassis-mounted components.

The Top Cover A8 mounts the A3 Controller and its A8VR1 and A8Q1, which use the Top Cover as a heatsink. The Display PWB A2 is secured to the Control Panel A1 which is mounted to the Top Cover using nuts, studs and an adhesive gasket. Access to these assemblies is gained by removal of the Shield. The Top Cover is electrically bonded to the Base assembly with two braided ground straps.

With the Top Cover open and the Shield removed, test probe access is gained to every component terminal in the unit. In this state, the unit remains fully functional. If it is necessary to close the top cover, the Shield should be reinstalled with at least one nut each at the top and bottom to prevent interference during high-power activation from disrupting the display processor and causing a HLP 12 shutdown.

Refer to Section 1.1.4 for Precautions When Testing or Servicing.

CAUTION: Turn off power and/or disconnect the power cord before removing any assemblies, connectors or components. Before applying power, remove any foreign objects which may have accidentally been dropped in the unit.

CAUTION: Hazardous voltages appear in the unit when it is connected to the AC mains. When activated, high voltage, high frequency power is present on the A5 Output Panel and on the A4 PWB in the area marked with lightning bolts.

CAUTION: Replace fuses only with the type and rating marked adjacent to the fuse clips or holders.

5.2.1 Top Cover

Refer to Figure 5.1 to locate the two Phillips head screws which secure the Top Cover. After these screws are removed, slide the top cover forward until it stops, then lift the front of the top cover, rotating it around its rear edge until vertical. The Top Cover may then be supported in the open position by sliding the slots in the Top Cover brackets on to the top edge of the rear panel. If necessary, the Top Cover may be opened while the unit is operating, provided care is taken to avoid dropping foreign objects into the circuitry.

Reverse this process to close the unit. Switch A3S1 to RUN before returning the unit to service. Avoid stressing the Top Cover ground straps when lifting the Top Cover off the rear panel. After the Top Cover is horizontal on the Base Assembly, slide it forward until the two front studs align with their mating slots in the Base Assembly, then push it rearward fully. Align the captive nuts in the Top Cover brackets with the screw holes in the rear panel, then start both screws loosely before tightening.

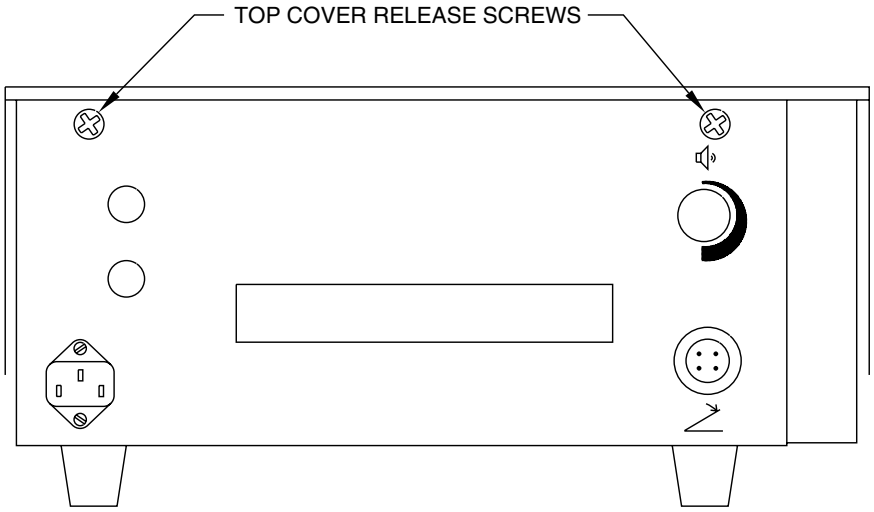

Figure 5.1 Access Fastener Locations

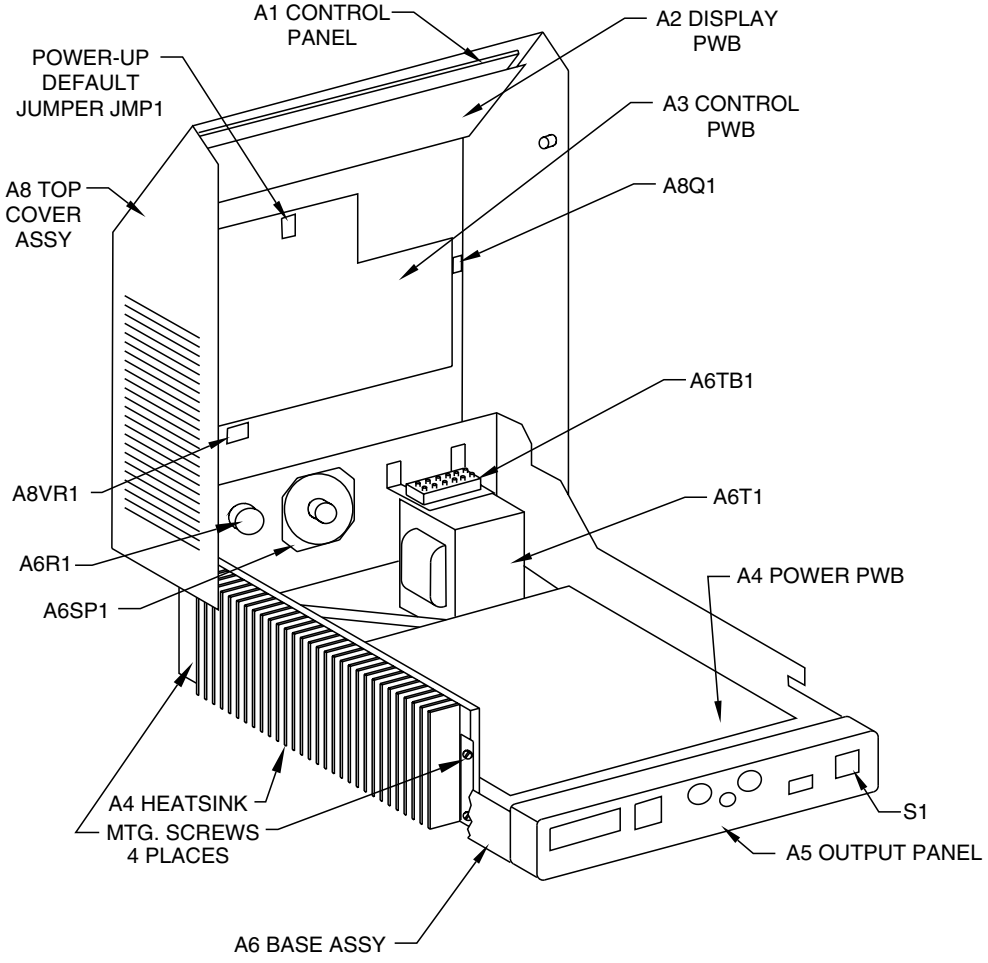

Figure 5.2 Major Assembly and Component Locations

5.2.2 Shield

As viewed from the front of the unit with the Top Cover open, the Shield is mounted with two nuts along the top edge, one on the left and one on the bottom. The four Shield mounting nuts may be removed using a 9/16" or 14mm nutdriver. Avoid dropping the nuts into the Base Assembly. After the nuts are removed, the Shield may be pulled free from its mounting studs and forward. A notch on the left side will clear the left hand Top Cover stud, permitting the Shield to be removed fully, left side first.

Reinstallation is by the reverse process. Avoid crushing harness wires with the bottom edge of the Shield. Install and tighten all four nuts before returning the unit to service. After the Shield is secured, check switch A3S1 for correct position before closing the Top Cover.

5.2.3 A4 Power PWB

The A4 Power PWB, the heatsink and its components and the heatsink support brackets are removed from the unit as a single assembly. Avoid stressing the PWB/heatsink joint during handling to prevent breaking bonding wires in heatsink-mounted components.

To remove the A4 PWB:

1. Disconnect the four connectors to the output panel, the two ribbon/DIP harnesses on the right side, the three brown 0.1" harness connectors central to the PWB, and the two white nylon power connectors along the rear. These connectors are keyed and labeled to ensure proper reconnection, so they need not be marked.

2. Remove the three nylon nuts along the front edge of the A4 PWB.

3. Remove the two mounting screws at the right rear corner and on the rear extension between J1 and C4. Do NOT remove the screw which secures the heatsink angle bracket on the rear center edge.

4. Working from the side of the unit, remove the four screws securing the front and rear of the heatsink to the Base Assembly.

5. Lay the disconnected harnesses aside. Lift the A4/heatsink assembly vertically out of the unit.

While the A4 PWB is out of the unit, take advantage of the opportunity to remove any debris which may have accumulated in the base pan.

Replacement of heatsink-mounted components requires special care. After the old device is removed, clear the solder pads fully. Inspect the heatsink insulators for damage or holes and replace if necessary. Use only Conmed-specification replacement insulator pads to ensure adequate heat transfer and dielectric strength. Form the leads of the replacement component accurately such that no stress is transferred to the package when it's tab is tightened down. Do not solder the leads until the tab and insulator are securely mounted to the heatsink. Tighten screws for Q8, 9 and 10 to 3 in-lb; these devices require compression washers to accommodate thermal expansion. The clips for the other three heatsink devices should be tightened to 8 in-lb.

Reinstalling the A4 Power PWB is the reverse process. Ensure that all harnesses are clear before inserting the assembly. After it is set in place, install all fasteners loosely. Tighten the four heatsink screws first, then the two rear PWB mounting screws, and the three front edge nylon nuts last. If the A4/heatsink assembly is being installed temporarily, install and tighten the two metal PWB screws to ensure ground integrity.

After the assembly is mechanically secure, install all nine harness connectors. All connectors are keyed to prevent reversal, but take care when installing the .156" nylon connectors to avoid getting one pin off to the side.

5.2.4 A3 Controller PWB

The A3 Controller PWB may be removed after opening the Top Cover and removing the Shield. Disconnect the two ribbon/DIP harnesses along the bottom edge, the two discrete harnesses at the right edge, the harnesses connecting TO-220 devices A8VR1 and A8Q2, the 4-pin dc power harness and finally the A2 ribbon harness along the top edge of A3. Then remove the six mounting screws.

CAUTION: The A3 Controller PWB contains static-sensitive devices. Take appropriate static control precautions during handling and service.

Reinstallation is the reverse process. Most of the connectors are keyed to ensure correct orientation. The dc power connector P2 should be installed with the ramps away from the PWB surface, and the two TO-220 harnesses should be installed with the raised tabs pointed away from the Top Cover surface. If A3 is being installed temporarily, install and tighten the bottom center screws and the top righthand screw to ensure ground integrity. Otherwise install and tighten all six mounting screws before installing the Shield.

Set A3S1 to RUN and secure the Top Cover before returning the unit to service.

5.2.5 A2 Display PWB

To remove the A2 Display PWB assembly, first remove the Power Control Knobs by unsnapping the knob caps, loosening the collet nuts and pulling the knobs free of the encoder shafts. Remove encoder bushing nuts using a 7/16" (11mm) socket. Set the flat washers aside with the nuts to prevent mixing them up with the spacer washers behind the panel.

With the Top Cover open and Shield removed, remove the four A2 PWB mounting screws. Pull the PWB away from the Control Panel until the encoder shafts are free, taking care to avoid dropping the encoder spacer washers in to the unit. Set these washers aside and separate from the outer flat washers.

With a sheet of insulating material placed behind the A2 PWB to prevent shorts, the unit may be powered up with the component side of A2 visible for troubleshooting. Complete removal of A2 requires disconnecting the ribbon cable from the A3 PWB, the flexcircuit connector to the Control Panel and the dc power harness. Avoid unnecessary stress on the Control Panel flexcircuit.

CAUTION: The A2 Display PWB contains static-sensitive components. Take appropriate static control precautions during handling and service.

Installation is the reverse process. Place spacer washers on the encoder bushings prior to mounting on the Control Panel; these washers are thicker than the flat washers used under the encoder bushing nuts. Install and tighten the four PWB mounting screws, then install the encoder flatwashers and tighten the encoder bushing nuts.

The Power Control knobs may be installed in any rotational orientation with respect to the encoder shafts. Allow a slight clearance between the knob skirts and control panel to provide free rotation. Tighten collet nuts adequately to prevent accidental removal, then snap the knob caps back in place. If colored caps are supplied, the yellow cap should be placed on the Cut knob. Reinstall the shield, set A3S1 to RUN and secure the Top Cover before returning the unit to Service.

5.2.6 A1 Control Panel

The A1 Control Panel need not be removed unless it is damaged or the membrane switches malfunction. Reinstallation requires replacement of the adhesive gasket which seals the panel to the Top Cover.

To remove the A1 Control Panel, first remove the A2 PWB. Remove the six remaining mounting nuts. Remove the flat washer and Control Panel shield layer grounds trap from the stud.

Working from inside the Top Cover, use a broad screwdriver or similar tool to break the gasket free from the Top Cover. Avoid deforming or gouging the Top Cover to ensure a watertight seal when the gasket is replaced. Remove the Control Panel and gasket as a unit. Remove all residue of old gasket material from the inside surface of the Top Cover. Clean the mating surface with isopropyl alcohol and dry thoroughly before installing the new gasket.

Inspect the new gasket to determine the side which faces the Top Cover; the holes fit over the Top Cover studs, and the pattern is not symmetrical. Carefully remove the release paper from the side of the gasket facing the Top Cover; do not touch the adhesive. Slip the gasket over the eight mounting studs. Neatly align the inside edge of the gasket with the edge of the Control Panel cutout in the Top Cover. With the gasket aligned, press it in place using moderate, even pressure to avoid bulges.

APPENDIX A
HLP CODES AND POSSIBLE CAUSES

See Section 4.5.1 and 3.5.1 for explanation:

HLP Code	Meaning (dependent on when performed as noted)	When Performed	Possible Causes
1	Read/Write ability of 8031 internal memory is impaired.	Initialization and operation	-Faulty A3U3(8031)
2	Program memory CRC check error.	Initialization and operation	-Faulty A3U1 (27C64) -Faulty A3U3 (8031) -Open or shorted Address, Control, or Data bus lines.
3	Calibration memory CRC check error.	Initialization and operation	-Calibration incomplete when exited CAL mode. -Faulty A3U2 (X2001) -Faulty A3U3 (8031) -Open or shorted address, control, or data bus lines. -Faulty A3U6 (74LS00) or A3U8 (74LS32)
4	Watchdog Timer pulse width is incorrect	Initialization	-WDT timing parts incorrect -Microprocessor frequency incorrect -Faulty A3U7 (4538) -Faulty A3U3 (8031) -Faulty A3U6 (74LS00) -Faulty A3U10 (74LS00)
4	Watchdog Timer detected WDTSTB outside of timing window.	Operation	-Faulty A3U3 (8031) -Faulty A3U1 (27C64) -Processor 10 Mhz clock frequency incorrect
5	RF PA supply current is out of range for test drive setting.	Initialization	-Incorrect base or gate drive -Shorted PA power transistor -A4D2 or RV1 shorted -A3J5 or A4P3 disconnected -IFAIL or VSENSE circuits faulty -Open fuses(s) or transistor(s) in PA -Bipolar relay stuck closed
5	RF PA supply current is too high for power setting.	Operation	-Incorrect base or gate drive -Shorted PA power transistor -A4D2 or RV1 shorted -VSENSE circuit faulty (cut modes) -Bipolar relay stuck closed

HLP Code	Meaning (dependent on when performed as noted)	When Performed	Possible Causes
6	Attempted entry into a guarded memory location or CPU failure.	Initialization and operation	-RF shield not in place -Faulty A3U3 (8031) -Faulty A3U1 (27C64)
7	Watchdog Timer hardware does not disable RF drive.	Initialization	-Faulty A3U5 -Faulty A3U13 -Faulty A3U23 -+12 supply on A3 incorrect -Faulty A3R50 or R51
8	Detection of a shorted hand or foot control	Initialization	-Shorted or pressed hand or foot control -Continuity detector failure -A3U11 (8255) failure -Shorted bypass caps on control lines
9	Attempted entry to Cal mode without "PAD" button pressed.	Cal Mode	-A3S1 set in Cal position -Faulty/Disconnected control panel -Faulty A2U1
10	Incomplete Cal	Cal mode	-One or more Cal points not calibrated on return to CAL menu.
11	Non-monotonic Calibration	Cal mode	-OPERATOR error when calibrating power -Faulty Waveform Generator -Faulty Base Voltage Generator -Faulty A3U2 (X2001)
12	The power setting in data memory does not match that displayed for this mode.	Operation	-RF shield not in place -Faulty A2U1 -Faulty A3U3 -Faulty bus connection to A2J2
13	Control Panel button stuck	Initialization	-Pushbutton shorted in control panel -A2U1 or RN1 defective -Operator error
21	A.R.M. voltage Less than +0.4V	Operation	-Shorted VARM sense line -Shorted A3VR1 -Shorted A4Q5 or Q6 -Shorted A4T2